STORM DRAINAGE DESIGN CHAPTER

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1.0 INTRODUCTION

1.1 Purpose of Storm Drainage Design Chapter

This chapter is intended to provide acceptable criteria, methods, and a framework within which the goals of storm drainage systems may be achieved in effective and efficient ways. In the event a conflict exists between requirements, the more stringent applies.

1.2 Laws, Ordinances, and Policies

It shall be the responsibility of the developer to be aware of all applicable laws, ordinances and policies associated with the storm water field for projects under design and construction. This design manual is not intended to supersede the laws and regulations of the Natural Resources Conservation Service, the Maryland Department of the Environment, or the State Highway Administration for storm drainage within the State Highway Administration right-of-way.

1.3 Easements, Ownership, and Maintenance

It is the City's policy to require that all storm drainage facilities, whether natural or improved, surface or subsurface, including storm water management facilities, to be within an easement, right-of-way or City owned lands.

a. Subsurface drainage facilities which convey drainage flow from a public right-of- way shall be enclosed within a drainage easement or City-owned lands.

b. Surface drainage facilities which convey drainage flow from a public right-of-way shall be enclosed within a drainage easement or City-owned lands.

c. Surface drainage facilities conveying storm water from upstream lots comprising a total area of less than one acre or one lot will not be required to provide a drainage easement, but the construction plans or the site development plans for the development shall show a drainage swale or underground pipe system which will accommodate the flow.

d. For natural drainage systems, the 100-year floodplain shall be enclosed by a "100-year floodplain and drainage easement" or City-owned lands, which shall be defined by bearings, distances and coordinate values; be tied to property lines; and show the floodplain elevations at all bearing changes and at intervals not exceeding 200 feet between bearing changes.

e. Storm water management practices which are to be maintained by the City shall be enclosed within a drainage easement or City-owned lands, which shall include a 20' minimum access surrounding the facility.

f. For improved channels, the 100-year floodplain shall be enclosed by a 100-year floodplain and drainage easement extending beyond the floodplain on both sides of the channel for purposes of access and maintenance.

1. For channels having a top width of 30 feet or less, the easement or right-of-way on one side of the channel shall extend beyond the 100-year floodplain to a line a minimum distance of 10 feet outside of the floodplain. On the opposite side of the channel, the easement or right-of-way shall extend beyond the 100-year floodplain to a line a minimum distance of 20 feet outside of the floodplain. The wider easement or right-of-way shall be located continuously on the same side of the channel between intersecting public roads, but may switch sides of the channel on the opposite side of a public road.

2. For channels having a top width in excess of 30 feet, the wider easement or right-of-way criteria shall apply to both sides of the channel.

g. Discharge and Drainage Easements: Discharge easements for the major drainage system will normally not be required from downstream property owners unless the point of discharge has been significantly altered in location or the size of the drainage basin has been significantly increased in area. Drainage easements for the major drainage system will normally not be required from upstream property owners unless one or more of the following conditions occurs:

1. The point at which the flow crosses the property lines is significantly altered in location. The developer will also be required to construct all facilities to direct storm water runoff to the new point of entry.

2. There is existing development upstream with a closed-conduit channel system and the hydraulic grade line or energy grade line at the next upstream structure is raised above its original or recomputed value.

3. There is existing development upstream with an open-channel system and the hydraulic grade line in the open channel at the property line is raised above its original or recomputed value.

4. There is undeveloped land upstream and a proposed project improvement, other than a bridge or culvert, would raise the hydraulic grade line at the property line above the 100-year floodplain based on the existing natural upstream channel and the ultimate runoff of the fully developed watershed. A flowage easement will be required only if the backwater or headwater at the property line exceeds the previously defined 100-year floodplain by one foot for a bridge or for a culvert. In no case shall an increase be allowed at the property line, with or without a flowage easement, if it causes flooding or increased flooding of existing structures.

h. All existing or proposed surface drainage facilities such as swales, streams, stormwater management facilities, unpaved and paved channels, etc., located within privately owned easements will be the legal responsibility of the property owner for operation and maintenance. The property owner(s) will be required to enter into an agreement with the City to allow the City to inspect and enforce proper maintenance procedures.

i. Surface drainage from contributing drainage areas shall be intercepted by an underground storm drain system of the proper size and conveyed to a suitable point of outfall. The underground storm drain system shall be properly designed to convey discharge volumes anticipated from ultimate development of the contributing drainage area. Storm drain inlets shall be spaced to limit contributing drainage areas as follows:

Slope of Drainage Channel Flowing Into Storm Drain (Percent)	Maximum Contributing Drainage Area (Acres)
1% - 2%	1.0 acres
2.1% - 5%	1.5 acres
+5%	2.0 acres

The flow depth within the open drainage channel shall not exceed 9 inches during the 10-year frequency storm.

Recognizing that it may not be possible or feasible, due to topography or underground impediments, to convey storm drainage the full length to an acceptable stream or other outfall via an underground pipe, the terminal length of the system may consist of an open swale or ditch properly lined to prevent erosion. Should the terminal end of the conveyance system be required to be an open swale or ditch, as determined by the City, the length of the open swale or ditch shall be the minimum and slope shall be the maximum needed to overcome topographic, underground impediments or other physical constraints.

(Revision approved at Mayor & Council meeting, 8/27/02)

1.4 Inspections

All public and private storm drain systems shall be inspected by the City of Brunswick, in accordance with City Inspection Procedures, at the expense of the developer.

2.0 SUBMITTALS

2.1 General Submission Requirements

2.1.1 Introduction

The Office of Planning and Zoning administers the review and approval process for all subdivision and land development projects and coordinates Capital Improvement Projects. Current information concerning applications, review fees, numbers of copies, etc., should be obtained from the City Public Works or the Office of Planning and Zoning.

In many cases, storm drainage facilities will be presented on roadway, site development, and other plans which include other improvements. If this occurs, the requirements for the storm drainage facilities shall be coordinated with the requirements for other improvements.

2.1.2 Design Computations

Appropriate hydrologic, hydraulic, geometric, structural, and other design computations, together with the environmental inventory and assessment, shall accompany all submissions for storm drainage improvements. If an appropriate form or table is not presented in the Design Manual, a suitable engineering style of computation shall be followed.

Complete sets of hydrologic and hydraulic design computations shall be included with all submission, review and record copies of plans involving storm drainage facilities. The materials may be included at the original size of the various computation tables and forms or they may be combined in sequence and reproduced on 24 inch x 36 inch sheets to match the size of the plan sheets. These items need not be included in sets of plans for bidding or construction purposes. In addition to those bound into the plans, two (2) copies or more, if required, of all storm drainage design computations shall be submitted in separate binders which will fit in a standard letter or legal sized file.

2.1.3 Specifications

All storm drainage construction shall meet or exceed the following specifications as appropriate:

a. State Highway Administration Specifications for Materials, Highway, Bridges, and Incidental Structures, latest edition for all work within the State Highway Administration's right-of-way.

b. 1994 Maryland Standards and Specification for Soil Erosion and Sediment Control or most current edition for all work within the City Boundaries.

c. Frederick County Plumbing Code, latest edition for work on private property.

d. Brunswick Standard Details and Specifications for Construction, latest edition, for all work within the City Boundaries and outside of County, State, or Federal land.

Specifications for items not covered in these specifications shall be submitted to the City for review and approval. Whenever a conflict exists between the standards mentioned herein, the most stringent requirement(s) will apply.

2.1.4 Quantities and Cost Estimates

In conjunction with other required public improvements, design engineers shall submit a tabulated estimate of all quantities and costs, including contingent items, for all storm drainage facilities, soil erosion and sediment control measures, and storm water management facilities. The City Public Works and City Engineer should be consulted for information relating to the latest format for both development and Capital Improvement Projects.

2.1.5 Easement Plats and Transmittal Sheets

Where storm drainage facilities will occur in areas outside of public roads and highways or easements to be shown on the project final subdivision plat, supplementary easement plats will be required. All storm drain utility easements shall be 30 feet minimum width. No other utilities will be allowed in the storm drain utility easement without the City of Brunswick's permission.

2.2 Specific Plan Requirements

2.2.1 Introduction

The purpose of this section is to indicate the specific requirements for storm drainage facilities, soil erosion and sediment control measures, and storm water management facilities as shown in the various plan submissions. The City's Subdivision Regulations provide requirements for plan submissions which shall include storm drainage facilities, easements, if applicable.

2.2.2 Drainage Area Map

Off-site drainage area maps shall be prepared from the largest practical and available scale topographic maps. On-site drainage area maps shall be prepared at the scale of project preliminary or site development plan. Preliminary drainage area maps shall be revised to reflect final design conditions if they are to be utilized for the final drainage area map.

The entire area under consideration shall be subdivided into areas tributary to entry or design point. Each tributary area shall be delineated by bold, dashed lines along its ridges. Sufficient flow arrows shall be shown to clearly indicate high points, direction of surface runoff, direction of gutter or channel flow and points of concentration. Final drainage area maps shall show all paths of drainage at street intersections, gutters and side road ditches.

2.2.3 Construction Plans

a. Construction plans involving storm drainage shall include, at a minimum, the following:

Grading Plans

Road Plans

Site Development Plans

Soil Erosion and Sediment Control Plans

Storm Water Management Plans

Storm Drainage Profiles

Detail Sheets

Structure and Pipe Schedule

Final Drainage Area Maps

Storm Drainage Plan-Profiles

1. Grading Plans: Separate grading plans may be required by the Office of Planning and Zoning if a road or site development plan is insufficient or too complex to portray area grading. These plans are normally prepared at the same scale as the preliminary or site development plan. They should show existing and proposed grades, contours, temporary or permanent drainage, existing features and be coordinated with the Soil Erosion and Sediment Control Plan.

2. Road Plans: These plans shall show the location and geometrics of the storm drainage system and its horizontal relationships with property lines, easements, public roads, and other existing and proposed improvements. This plan shall also show the drainage system identification, size, structure schedule and flow directions.

3. Site Development Plans: Site development plan requirements are delineated by the subdivision and land development regulations. Insofar

as storm drainage is concerned, they fulfill essentially the same function as roadway plans. Additionally, they are often utilized to indicate the 100-year floodplains, grading, soil erosion and sediment control, if separate plans are not to be prepared. Floodplains shall be determined.

4. Soil Erosion and Sediment Control Plans: These plans are usually prepared on a reproducible copy of the preliminary grading or site development plan and hence have the same scale as these plans. They shall show the location and geometrics of the erosion and sediment control measures and the horizontal relationships of them with property lines, easements, public roads, and other existing and proposed improvements. This plan should also show necessary seeding and other specifications, construction sequences, details, watersheds being served by sediment basins, and certifications. The Natural Resources Conservation Service should be consulted for the latest requirements.

5. Storm Water Management Plans: These plans are utilized if other plans are not appropriate to show the storm water management facilities. A reproducible copy of the preliminary grading or site development plan may often be utilized for this plan. This plan serves the function of all plans for the horizontal location of the improvements. In addition, this plan shall also show necessary specifications, special details or structures, watersheds being served, maintenance responsibilities, and certifications.

6. Storm Drainage Profiles: Storm drainage profiles are utilized in conjunction with some type of plan which shows the horizontal aspects of the storm drainage facility. Storm drain profiles shall show the existing and proposed grade of closed conduits, the conduit size, type, class, length, slope, upstream and downstream invert elevations, structure invert development and designations, design discharge, full-flow velocity and part-full velocity, if the last was computed. In addition, the profiles shall state and show graphically the locations of the hydraulic grade line as specified. For open channels essentially the same information shall be shown except that both the water surface and energy grade line profiles shall be stated and shown graphically. Approximately 400 feet upstream and downstream of the water course shall be shown.

7. Detail Sheets: If other types of plans or profiles are insufficient, detail sheets may be necessary. They contain architectural, structural, and other elements of any special details. They are prepared to an architectural scale, usually 3/8 inch = 1 foot for simple details and as large as 3 inches = 1 foot for highly complicated details. They shall clearly present all information necessary for the fabrication or construction of the item. For significant structures subsurface exploration data, design standards,

loadings, foundation pressures and design stresses shall be given. Major material categories or specifications shall also be given.

8. Final Drainage Area Maps: These represent a refinement of the preliminary drainage area maps.

9. Storm Drainage Plan-Profiles: This special type of plan is utilized if the drainage facility is the major improvement. Scales will be similar to those for road plan-profiles. These plans shall contain essentially the same information contained in the previously described plan types and the separate storm drainage profiles.

10. Structure Schedule and Pipe Schedule.

11. The appropriate number of the final plans, as determined by the Planning and Zoning Office, shall be submitted to the Office of Planning and Zoning for use by the City in updating the City's system maps.

12. As-Built drawings are required to be submitted with the Request for Conditional Acceptance in addition to the Request for Final Acceptance for review and approval. Once approved, the appropriate number of the As-Built drawings on mylar plan sheets with the statement and Engineer's signature, as shown in the Appendix, and City Approval Block shall be submitted to City Hall prior to Final Acceptance of the work by the City and on computer or GIS diskette in a format approved by the City Public Works, City Engineer, and the Office of Planning and Zoning.

2.2.4 Final 100-Year Floodplain Determination

In addition to the necessary computations, the following shall be submitted:

a. Channel and floodplain cross-sections plotted on full cross section paper (1 inch = 20 feet or 50 feet horizontal, and 1 inch = 5 feet vertical) or presented as computer plotter output. Indicate Manning n factor for each subsection of cross section.

b. Channel profile (1 inch = 100 feet horizontal and 1 inch = 10 feet vertical, or 1 inch = 50 feet horizontal and 1 inch = 5 feet vertical) plotted on full cross section paper or computer plotter output with the channel meander used as the horizontal length and showing the tops of channel banks, water surface, energy grade line, and distribution of flow and average velocities for overbanks and channel, if available.

2.2.5 Final Subdivision Plat

For storm drainage, the plat shall show drainage easements, 100-year floodplain limits and elevations, maintenance responsibilities and dedication statements.

2.2.6 Capital Improvement Projects

Capital Improvement Projects shall meet the same general criteria as the developer projects and shall meet the site-specific project scope of services.

2.3 Review and Approval

Storm drainage submissions will be reviewed by the following agencies for compliance with the given requirements:

a. City Public Works, City Engineer, and the Office of Planning and Zoning for compliance with the Subdivision and Land Development Regulations and for compliance with the following:

1. Subdivision and Land Development Regulations

2. Design Manual

3. Grading Permit

4. Storm water management inspection schedule, reports and requirements during construction

5. Storm water management maintenance and maintenance agreement

b. Other City or Frederick County agencies for compliance with the subdivision and land development regulations.

c. Natural Resources Conservation Service and Maryland Department of the Environment, as appropriate, for compliance with 1994, Maryland Standard Specifications for Soil Erosion and Sediment Control and NRCS criteria for the design of dams and ponds for storm water management.

d. Department of Transportation, State Highway Administration for compliance with its design practices, criteria and specifications for construction within its rights-of-way for an access permit.

e. Maryland Department of the Environment for issuance of a permit involving construction in a major floodplain or a major dam and reservoir where drainage area is 200 acres or greater for Class I and Class II waterways and 100 acres for Class III and Class IV waterways.

f. U.S. Department of Housing and Urban Development, Federal Insurance Administration for compliance with its criteria and regulations for floodplain delineation for Federal Flood Insurance.

g. U.S. Army Corps of Engineers for permit.

3.0 STORM DRAIN DESIGN STANDARDS

3.1 Criteria and Procedures

The criteria and procedures for design shall be consistent with approved environmental practices and existing laws and regulations which are concerned with storm water runoff. They are also intended to be compatible with the Natural Resources Conservation Service, Maryland Department of the Environment, and the requirements of other State and County agencies as they pertain to the City of Brunswick.

3.2 Topographic and Land Use Maps

Topographic maps shall be obtained from the Office of Planning and Zoning, if available. If additional or supplemental topography or planimetric mapping is needed, the Developer shall be responsible to secure the information. Zoning and approved land use maps are available from the Office of Planning and Zoning.

3.3 Drainage Problems Not Covered Herein

When a specific drainage problem is encountered which is not covered in the Section, it will be the responsibility of the Engineer to furnish the City Public Works, City Engineer, and the Office of Planning and Zoning with calculations and other data supporting his design.

4.0 HYDROLOGY

4.1 Rational Method

The rational method may be used for homogeneous drainage basins of 100 acres or less for closed storm drain systems. For drainage basins greater than 100 acres, but less than 500 acres, it may be used for determination of peak runoff only. Ultimate conditions shall be determined based on the City of Brunswick Master Plan. Existing and pre-developed conditions shall be determined based on 1" = 200' scale or large topography and field recommendations. The rational method may not be used for storm water management design, culvert or bridge crossings. With the rational method, the peak discharge at any point may be determined by the formula: $Q = CIA$

In this formula:
Q = the peak discharge in cfs
C = the runoff coefficient

I = the average rainfall intensity in inches per hour
A = the drainage area in acres

For clarity: in/hr x acres = 1.008 cu ft/sec

4.2 Hydrograph Methods

The size of the drainage area shall be limited to 500 acres maximum and shall be homogenous with respect to the time of concentration and land use. The latest version of Natural Resources Conservation Service (NRCS) TR-55 "Urban hydrology for Small Watersheds" may be used for small watersheds. The latest version of NRCS TR-20 "Computer Program for Project Formulation-Hydrology" may be used for areas greater than 500 acres.

4.3 Rainfall Intensity (I)

Use the NRCS Type II rainfall distribution for a 24-hour storm and antecedent moisture condition II.

4.4 Time of Concentration (T_c)

4.4.1 How Determined: The time of concentration consists of the sum of the inlet time and the time of flow in the system from the most hydraulically distant point in the drainage area to the point under consideration. Inlet time includes time for establishment of flow and time in swales, ditches, gutters, etc. An acceptable average value of the inlet time as a function of percentage impervious area may be obtained from the following relationship: $T_i = 15.0 - PI/8$ in which T_i is the inlet time in minutes and PI is the percent impervious area within the inlet area under investigation.

4.4.2 By Zoning Classification

a. Minimum Inlet Time: Shall be 5 minutes regardless of zoning classifications.

b. Maximum Inlet Time: For zoning classifications with an allowable percent impervious area greater than 50%, the maximum allowable inlet time shall be 7 minutes.

4.5 Runoff Coefficients (C)

The runoff coefficient is a factor which relates the runoff rate to the rainfall intensity. This coefficient is dimensionless and takes into account the percent impervious, soil type, and slope of contributing drainage area.

Average values of runoff coefficients are shown in Table 2 for various land uses. A composite "C" value for the drainage area under consideration is computed in an area-weighted average of the individual runoff coefficient of the various sub-areas of the watershed.

4.6 Special Considerations

4.6.1 Partial Area Contribution

In some watersheds, particularly if there are large amounts of impervious areas near the downstream portions of the basin, the peak rate of runoff may be realized when only these areas are contributing. Because the design intensity will be based on their shorter time of concentration, rather than the longer time of concentration for the entire watershed, the discharge may be greater than when the entire watershed contributes at a reduced intensity and runoff coefficient.

4.6.2 Apparent Reduction in Peak Discharge

In many watersheds, particularly where the mainstream channel is in a natural condition and there are not significant tributaries, the intensity values associated with time of concentration based on the travel time in the mainstream will decrease faster than the total area of the watershed increases. This results in a decrease in the product of I times A and, hence, the peak runoff shall not be decreased, but the greatest upstream value of peak runoff shall be used until a point is reached for which the peak runoff rate again increases.

4.7 Watershed Modeling

4.7.1 Soil Conservation Service TR-20

The NRCS's Technical Release No. 20 "Computer Program for Project Formulation-Hydrology" is a valid approach to hydrologic modeling of watersheds and should be considered when any of the following conditions exist:

a. Watersheds are larger than 500 acres.

b. There are many sub-area with different runoff characteristics.

c. Reservoirs and dams are either existing or proposed.

d. Historical storm events need to be analyzed.

e. A complete flood hydrograph is desired.

4.7.2 NRCS's Tabular Method

Smaller watersheds may be analyzed using the NRCS's Tabular Method as described in Technical Release No. 55, "Urban Hydrology for Small Watersheds."

4.7.3 Other Models: Other hydrologic computer programs may be used with prior approval of the Office of Planning and Zoning. A user's manual and complete input data and printout must be submitted for each project.

5.0 HYDRAULICS

5.1 Closed Conduit Flow

5.1.1 Size of Drains: Shall be established as follows:

Q = a v where:

Q = Quantity of flow in cfs.

a = Required area of conduit in square feet

v = velocity in feet per second

5.1.2 Velocity: Shall be determined by the Manning Formula:

$v = \frac{1.486}{n} r^{2/3} s^{1/2}$ where:

n = coefficient of roughness

r = hydraulic radius in feet = $\frac{\text{cross-sectional area}}{\text{wetted perimeter}}$

s = slope of hydraulic gradient in feet per foot

5.1.3 Minimum and Maximum Velocities: The minimum velocity shall be 2 fps, and the maximum velocity shall be based on boundary surface material and shall not exceed 25 fps.

5.1.4 Manning's Coefficient (n): The selection of a friction coefficient involves a consideration of not only the initial but also the future conditions of the boundary surface material. Also hydraulic conditions such as velocity and disturbing influences such as joints, alignment, variations in cross-sections, etc. will affect selection. Design values for man-made conduits are given in Table 3.

5.1.5 Hydraulic Gradient: The hydraulic gradient is a line connecting points to which water will rise in manholes and inlets, etc. throughout the system during the particular design flow. The hydraulic gradient shall begin at the downstream end of the proposed drainage system. Where a proposed drainage system is connected to an existing system, the hydraulic gradient at the point of junction shall be determined from existing plans on file with the Office of Planning and Zoning.

Where there are no record drawings available which indicate the elevation of the existing hydraulic gradient, it shall be the Engineer's responsibility to determine this elevation.

Closed conduit design shall be based on the hydraulic grade line method with pipes assumed to be flowing full. The losses are applied through the structures. The losses are identified and applied as follows:

a. Loss at entrance

$$h_e = Ke \frac{V^2}{2g}$$

b. Loss due to bends

$$hb = K_b \frac{V^2}{2g}$$

c. Loss at Junctions

The controlling angle is used to calculate the loss at the structure.

d. Loss for the length of the pipe.

One equation that can be used is:

$$h_L = 2.87\, n^2 \frac{LV2}{d^{4/3}}$$

5.2 Open Channel Flow

5.2.1 Size of Required Waterway

The waterway area required shall be determined from the relationship:

$$Q = AV \text{ and Mannings Formula } V - \frac{1.486}{n} r^{2/3} s^{1/2}$$

5.2.2 Minimum and Maximum Velocities

Minimum velocities for improved channels shall be 3 fps. The maximum velocities will be controlled by the erodibility of the lining. The maximum velocity shall not normally exceed 25 fps for non-erodible lining. For allowable velocities in erodible and non-erodible channels, see Table 5.

5.2.3 Manning Coefficients (n)

Design values for man-made channels are well established and are given in Table 3. Natural channels are subject to more variants and present a complex problem. For an extensive treatment of natural channels, the Engineer is referred to Chow, V.T. "Open Channel Hydraulics."

5.2.4 Water Surface Profiles

a. Improved Sections: The solution of the Manning equation often involves a trial-and-error process. However, numerous tables, graphs and capacity charts are available for a variety of channel slopes to facilitate computation, and any of these expedients resulting in sufficient accuracy may be used for design.

b. Natural and Irregular Sections: Streams and channels with irregular and varying "n" coefficients are usually analyzed by the following methods:

   1. Standard Step Method: For sample computations, the designer is referred to King, H.W. "Handbook of Hydraulic" and Chow, V.T. "Open Channel Hydraulics."

   2. U.S. Army Corps of Engineer Computer Program HEC-2 may be used for design without documentation, providing a complete listing of all input data, including cross-sections, is furnished along with the complete printout.

5.3 Energy Dissipators and End Treatment

5.3.1 Determination of Maximum Outlet Velocity

In all cases, the partial depth velocity shall be checked to determine the maximum outlet velocity to be used in the design of the end treatment.

5.3.2 Drop Structures

One of the most effective means of dissipating energy in channels is the drop structure (abrupt or steeply sloping). Whichever method is employed, sufficient data is to be furnished to support the design.

5.3.3 Stone-Filled Wire Baskets (Gabions)

Wire baskets of various sizes offer an effective means of dissipating velocities at the ends of structures and/or to construct checks or drops in channels. The Engineer is referred to Federal Highway Administration Hydraulic Design Series Nos. 11 and 15 for more specific design criteria. Sizing the stone is critical and will require design and analysis of the velocities for various states of flow. Wire baskets shall be vinyl coated.

5.4 Culverts

5.4.1 Losses Through Culverts

The determination of losses through culverts is well documented in various texts. The Engineer is referred to the FHWA Hydraulic Design Series Nos. 5 and 10 and the U.S. Army Corps of Engineers Computer Program HEC-2 for specifics concerning the design of these structures.

5.5 Bridges

5.5.1 Losses Through Bridges

The determination of losses or the amount of backwater produced through a bridge is complex, and the Engineer is referred to FHWA Hydraulic Design Series No. 1, "Hydraulics of Bridge Waterways" and the U.S. Army Corps of Engineers Computer Program HEC-2 for specifics concerning the design of these structures.

The minimum freeboard between the underside of the superstructure and the design high water shall be 2 feet, based on the 100-year frequency storm with ultimate development using current zoning.

5.6 Reservoir Routing

5.6.1 Drainage Areas Less Than 2,000 Acres

These shall be designed in accordance with the NRCS criteria established in Technical Release No. 55, Engineering Memorandum No. 378, and Engineering Memorandum No. 2.

5.6.2 Drainage Areas Greater Than 2,000 Acres

The design method shall be approved by the Office of Planning and Zoning.

6.0 COLLECTION AND CLOSED SYSTEM DESIGN

6.1 Specific Design Criteria

6.1.1 Design Storm Criteria

a. Minor drainage systems with flows of less than 10 c.f.s. shall be designed for the 10-year storm as a minimum, except as required in 6.1.1.(b) (c) (d) and Section 7.0.

b. When a closed conduit system is installed to replace an open swale drainage system serving drainage areas of 25 acres or more and/or having a 10-year discharge of 100 cfs or more, the system shall be designed for the 100-year storm.

c. Culverts and/or bridges which are in the 100-year floodplain shall pass the 100-year design storm. The ultimate conditions 100-year storm shall not have more than a one-foot increase in backwater above the existing conditions. A one-foot freeboard is required for the ultimate conditions 100-year storm.

d. The following minimum storm frequency criteria must be met for storm drain systems and culverts:

1. Cul-de-Sac Street 10 year

2. Local Road 10 year

3. Collector Road 25 year

4. Arterial Road 50 year

In the event the City believes that a greater year storm frequency should prevail for the design of storm drain systems due to concerns over excessive private or public property damage, disruption of public services, flood damage, or other undesirable impacts that may result from implementing the minimum criteria described herein, the City, at its sole discretion and with the approval of the Planning Commission, may require more stringent criteria be followed in the design.

The roads cannot be flooded on the above storm frequency. The water surface elevation should be a minimum of one-foot below the outside edge of the shoulder.

e. The inlet spacing shall be based on the 2-year ultimate condition storm and an eight foot (8') maximum spread onto the pavement measured from the face of the curb.

6.1.2 Basic Equations

a. $Q = A_1V_1 \quad = A_2V2$

Q = Discharge in cfs
A = Cross-sectional area in ft^2

V = Velocity in fps

The subscripts designate different channel or conduit sections.

b. $$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

V = velocity in fps
n = Manning coefficient
R = Hydraulics radius in ft.
S = Friction slope in ft/ft.

c. For pipes flowing full

$$V = \frac{0.59}{n} D^{2/3} S^{1/2}$$

6.1.3 Minimum and Maximum Velocities

a. The minimum velocity in storm drains shall be 2 fps.

b. The maximum velocity in storm drains shall be 25 fps.

6.2 Hydraulic Design Criteria

6.2.1 Hydraulic Grade Line Method

Closed conduit systems shall be designed by the hydraulic grade line method which assumes pipes to be flowing full. In this method, structure losses are approximated by nearly constant functions of velocity head of the incoming or outgoing flow. The losses are applied through a structure.

The hydraulic grade line in a structure or access point shall be below the top of the grade or curb's opening for the design storm and at or below the curb for the 100-year storm.

6.2.2 Future Extensions

Consideration shall be given to possible future extensions of the system.

6.3 Gutter and Street Flow

6.3.1 Flow Spread Requirements

Maximum permissible spread for flow in a curbed street shall be eight feet (8') for the two-year ultimate condition storm event.

Computations shall be based on the following equation:

$$\frac{Q_n}{y^{8/3}\, s^{1/2}} = 0.56$$

Q = discharge in cfs
Z = the reciprocal of the pavement cross slope or side slope in ft/ft
For example, for 1/4"/ft or 2.08% cross-slope, Z = 48)
n = Manning coefficient (normally 0.015 for pavement)
S = gutter slope in ft/ft
y = depth of flow in feet

6.3.2 Gutter Capacity

The gutter capacity cannot be exceeded; i.e., the curbs cannot be overtopped for the 100-year storm.

6.4 Inlet Design

6.4.1 Type of Inlet

State Highway Administration (SHA) Standard COG or COS inlets must be used where curbs are either existing or proposed. Grated inlets shall be SHA WR bicycle safe grates and shall generally be used only in pavement swales such as occur in parking lots and alleys or yard areas.

6.4.2 Where Required

Inlets shall be constructed in all sumps, regardless of flow volume, and at all intersections where flow exceeds 2 c.f.s. or the spread onto the pavement exceeds eight feet (8') and at intermediate points along street where criteria for gutter capacity will be exceeded. Pipes shall have a capacity equal to or greater than design flows, and inlets shall intercept a minimum of 85 percent of the design flow. Any carry-over flow must be accounted for at the next downstream inlet and shown on the Engineer's calculations.

6.4.3 Weep Holes or other temporary measures shall be installed in the catch basins for interception of runoff from the street until the final hot mix asphalt surface coarse has been installed or at the direction of the City or Sediment Control Inspector.

6.5 Closed Conduit Design

6.5.1 Manholes

a. Where used: Shall be used at all change in pipe size and where there is a change in direction.

b. Spacing: Maximum spacing of manholes shall be 400 feet.

c. Alignment: The horizontal alignment of pipe shall be straight line between access points and perpendicular to the road centerline if the pipe crosses the road, wherever feasible. At all inlets, manholes, etc., the invert of the pipe's upgrade shall be a minimum of 0.1 foot above the invert of the pipe downgrade.

6.5.2 Clearance with Other Utilities

For drains nearly parallel to other utilities, a minimum physical horizontal clearance of 5 feet shall be maintained. A minimum physical vertical clearance of 18 inches shall be maintained. Clearances less than this must be approved by the Office of Planning and Zoning.

6.5.3 Minimum Cover

Minimum cover for pipe in roadway shall be 18 inches, measured from the top of the pipe to the finished grade.

6.5.4 Size of Drains

Closed conduit systems shall be sized pursuant with the preceding hydraulic criteria, and the minimum pipe size shall be 15-inch diameter or equivalent.

6.5.5 Materials

All storm drain pipe shall be reinforced concrete pipe, Class III minimum, and required to meet State Highway Administration bedding conditions. Pipe joints shall be sealed with o-ring rubber gaskets.

The following minimum construction methods shall apply:

a. Backfill under the haunches of the pipe shall be hand-placed and tamped.

b. The backfill shall be placed in 6-inch layers equally on each side of the pipe and shall be thoroughly compacted to a minimum of 95% Modified Proctor Density in pavement areas and 90% in unpaved areas.

6.5.6 Foundations

In all cases, adequate bedding conditions shall be provided for drains. The Engineer shall detail on the Plans acceptable methods for supporting drains on unstable soil or fresh fill. Soil borings shall be taken if it is presumed that rock exists in the area or the suitability of material must be determined in order to adequately design the facility. A minimum of 3 inches of gravel bedding shall be placed below the pipe and bedded in gravel up to the spring line of the pipe.

6.5.7 Pipe Loadings

a. Foundation Designs in Specific Locations: Borings will be required for foundation designs in locations where the quantity of runoff requires a 72-inch diameter pipe or larger waterway area. The Engineer shall be governed by the analysis and recommendations of the Soils Engineer for foundation or pipe bedding designs.

b. Pipe Depths and Widths: In locations where the width of pipe trenches exceeds the standard maximum trench width, the loading on the pipe equals a projecting condition, and the design shall be based on positive projecting pipe loadings.

c. For Designs not Included Herein: The design of pipes and/or conduit shall be in accordance with the method presented in ASCE "Design and Construction of Sanitary and Storm Sewers", Chapter 9, Structural Requirements.

7.0 OPEN CHANNEL DESIGN

7.1 Swales, Roadside and Shoulder Ditches

These and other minor waterways having a design flow of less than 10 cfs shall be designed based on a 10-year storm frequency except as required in Section 6.1. All other open channels, improved or natural, shall be designed based on a minimum 50-year storm frequency or consistent with the criteria described in Section 6.1.1(d). Open swales or ditches shall not be used to convey storm water from a drainage area greater than one acre in surface area unless an open swale or ditch is necessary at the terminal end of the system to transition to an acceptable outfall, as discussed in Section 1.3(i).

7.2 Waterway Depth

Maximum waterway depth for all improved channels shall be two (2) feet.

7.3 Freeboard

Generally, freeboard shall be 30 percent of the design depth. This is an approximation. The minimum freeboard shall be 1.0 foot.

7.4 Velocities

a. For non-erodible linings the maximum velocity shall be 25 fps and the minimum velocity shall be 3 fps.

b. For vegetative and natural linings, see Table 5.

7.5 Open Channel Design Criteria

a. The design storm will be based on ultimate development.

b. The time of concentration will be based on:

1. the replacement of hydraulically inadequate bridges and/or culverts upstream of the project or within the project.

2. ultimate development.

c. Manning's coefficient based on

1. existing conditions unless changes in the coefficient are included in the proposed project.

2. the highest seasonal variation of the coefficient.

d. For improved channels, the profile and velocities of the natural stream shall be examined, both upstream and downstream of the proposed development for the following locations:

1. at the beginning and end of the improvement for all projects,

2. five (5) feet for all projects,

3. two hundred (200) feet for projects with drainage areas less than 50 acres,

4. five hundred (500) feet for projects with drainage areas between 50 and 200 acres,

5. one thousand (1000) feet for projects with drainage areas greater than two hundred (200) acres.

e. Riprap for energy dissipators and for bend locations shall be sized for the 100-year storm velocity.

f. If the headwall or bridge height above the channel bottom exceeds five (5) feet, or is within three (3) feet of a sidewalk, then channels which do not require a safety fence shall be provided with guard rails, or other safety device.

g. In non-erodible channels, the flat bottom may be sloped one to two percent to the center to define a low-flow channel.

h. The waterway depth based on the design storm shall be two (2) feet or less for all improved channels.

i. The minimum longitudinal slope of open drainage swales shall be 1.0 percent.

8.0 CULVERTS

8.1 Guardrails, Fences and Pipe Rails

Safety devices shall be required at all headwalls, as deemed appropriate by the Planning Commission.

8.2 Structural Borings

Structural borings to determine character and bearing capability of in-site material underlying foundations shall be provided for all single cell or pipe culverts of an opening size greater than twenty (20) square feet.

For the purpose of this design manual, a culvert shall be defined as a structure under a roadway or other embankment, open at each end, placed for the purpose of conveying a natural stream, waterway, or storm drainage.

8.3 Culvert versus Bridge

In general, the City of Brunswick will only approve culverts for stream crossings. If the Developer or his Engineer believes that only a bridge structure will satisfy the hydraulic, environmental and other prevailing criteria, the Engineer shall submit written analysis comparing the use of culvert and bridge. The analysis should include capital costs, maintenance costs, traffic maintenance, soil conditions, rights-of-way, and hydraulics and environmental impacts.

8.4 Inlet Protection

The inlet of all culverts shall be provided with a headwall or some other acceptable means of terminating the pipe and protecting the culvert from erosion.

8.5 Outlet Protection

It shall be the Engineer's responsibility to determine the need for erosion protection at the culvert due to excessive velocities. Outlet velocities shall be compared to stream velocities at the site under consideration to determine the need for erosion protection. The Engineer shall furnish data which supports the lack thereof for erosion protection.

8.6 Structural Design

The structural design of reinforced concrete box culverts shall be in accordance with the "Standard Specifications for Highways and Bridges", adopted by AASHTO. Culverts shall be sized using FHWA Design Series 5 and 10 and the U.S. Army Corp of Engineer's Computer Program HEC-2.

8.7 Minimum Freeboard

The minimum freeboard between the underside of the superstructure and the design storm water surface elevation shall be one (1) foot. The headwater of the structure shall be as close to the existing water surface elevation as possible. In trout streams, one culvert shall be one (1) foot lower than the final grade elevation.

8.8 Minimum Length

The minimum length of the culvert shall be based on providing for a 1/4 inch per foot graded area eight feet (8') behind the curb or two feet (2') behind the sidewalk, whichever is greater, and a side slope of 3:1 from this point.

9.0 BRIDGES

9.1 General

Bridge design is too broad a subject to be treated herein. However, the following guidelines are to be considered.

9.1.1 Where Used

Bridges shall be used for those cases where:

The quantity of flow to be passed is too great for a culvert;

Obstructions on the floodplain are to be avoided; or

Preservation of natural stream conditions is warranted.

9.1.2 Minimizing Lateral Forces

To minimize lateral forces on the structures, water must pass beneath the bridge without a standing headwater pool as is normal for a culvert. This requires the superstructure to be raised higher than that of a comparable box culvert.

9.1.3 Problems for Waterway Openings

Two of the foremost problems with bridge construction for waterway openings are the protection of the substructure from scour and erosion and the minimization of waterway obstruction. The placing of abutments and piers in the deepest flowing parts of the stream is prohibited.

9.1.4 Additional Considerations

a. To minimize accumulation of debris, stream crossings shall have as few supports in the waterway opening as possible, and all should be avoided if the flow is super-critical.

b. Embankments and grading around the substructure of a bridge shall be protected where necessary with either cast-in-place concrete slope protection or other acceptable methods.

c. The entire substructure of a bridge should be fitted in with the natural layout of the channel in such a way that hydraulic disruption is minimized.

d. The leading and trailing edges of piers in the stream should be either rounded or wedge-shaped to pass the water with a minimum of resistance and reduce possible scour from eddy currents.

e. Bridge design shall be in accordance with the "Standard Specifications for Highway Bridges", adapted by AASHTO officials, current State Highway Administration practices, and the current Maryland Department of the Environment regulations. Plans shall show all pertinent structural data such as design loadings, pressures and allowable stresses.

9.1.5 Piers and Abutments

The depths of bridge piers and abutment footings shall be established with respect to the character of the foundation materials and the possibility of undermining as determined from structural borings and soundings.

9.1.6 Footings

Except where solid rock is encountered, or in other special cases, footings which are exposed to the erosive action of stream currents, preferably shall be founded at a depth of not less than 8 feet below the stream bed. The above preferred minimum depths shall be increased as conditions may require. Footings not exposed to the action of stream currents shall be founded on a firm foundation and below the frost line.

10.0 ENERGY DISSIPATORS AND CHANNEL PROTECTION

10.1 Drop Structures

One of the most effective means of dissipating energy. Sufficient data must be furnished to support design.

10.2 Gabions

Wire baskets of various sizes offer an effective means of dissipating velocities at the ends of structures and/or to construct checks or drops in channels. Gabion wire baskets shall be vinyl coated in all cases.

10.3 Riprap

Stone may be used to dissipate velocities at the ends of structures and to line channels. The stone is to be sized for the design storm's velocity.

TABLE 1

HYDROLOGIC SOIL GROUPS
FOR FREDERICK COUNTY

Soil	Group
Athol	B
Augusta	C
Bermudian	B
Birdsboro	B
Bowmansville	D
Braddock	B
Brandywine	C
Bucks	B
Captina	C
Cardiff	B
Catoctin	C
Chalfont	D
Chandler	C
Chester	B
Chewacla	C
Clymer	B
Colbert	D
Conestoga	B
Congaree	B
Croton	D
Dekalb	B
Dullield	B
Edgemont	B
Elioak	B
Elk	B
Fauquier	B
Glenelg	B
Grenville	C
Hagerstown	B
Highfield	B
Huntington	B
Lantz	D

Soil	Group
Legore	C
Lehigh	C
Lindside	C
Linganore	C
Manor	B
Melvin	D
Montalto	B
Myersville	B
Norton	B
Penn	C
Raritan	B
Readington	C
Roanoke	D
Rohrersville	D
Rowland	C
Sequatchie	B
Thurmont	B
Urbana	B
Watchung	D
Waynesboro	B
Wehadkee	D
Worsham	D

TABLE 2

RATIONAL FORMULA COEFFIENCIENTS

SEE FOLLOWING PAGES

RAINFALL – RUNOFF DEPTHS IN INCHES

	DESIGN STORM YEAR AND RAINFALL INCHES						
RCN	1 YR. 2.5”	2 YR. 3.1”	5 YR. 4.0”	10 YR. 5.0”	25 YR. 5.4”	50 YR. 6.1”	100 YR. 7.0”
60	0.17	0.37	0.76	1.30	1.54	1.99	2.61
61	0.20	0.40	0.81	1.37	1.61	2.07	2.70
62	0.22	0.44	0.86	1.44	1.68	2.16	2.88
63	0.25	0.47	0.92	1.51	1.76	2.25	2.91
64	0.26	0.51	0.97	1.58	1.84	2.33	3.00
65	0.30	0.55	1.03	1.65	1.92	2.42	3.10
66	0.33	0.60	1.09	1.73	2.01	2.51	3.20
67	0.36	0.64	1.15	1.81	2.09	2.61	3.31
68	0.38	0.68	1.20	1.88	2.16	2.70	3.41
69	0.42	0.72	1.27	1.96	2.25	2.79	3.51
70	0.45	0.77	1.33	2.04	2.33	2.88	3.61
71	0.49	0.82	1.39	2.11	2.42	2.98	3.72
72	0.53	0.87	1.46	2.19	2.51	3.08	3.83
73	0.57	0.92	1.53	2.28	2.60	3.17	3.94
74	0.61	0.97	1.60	2.37	2.69	3.28	4.05
75	0.65	1.02	1.67	2.44	2.77	3.36	4.15
76	0.69	1.08	1.74	2.54	2.87	3.47	4.26
77	0.74	1.14	1.81	2.62	2.96	3.56	4.36
78	0.79	1.20	1.89	2.72	3.06	3.67	4.48
79	0.84	1.26	1.96	2.80	3.15	3.77	4.58

Reference: “SCS-TR-55”

RAINFALL – RUNOFF DEPTHS IN INCHES

	DESIGN STORM YEAR AND RAINFALL INCHES						
RCN	1 YR. 2.5"	2 YR. 3.1"	5 YR. 4.0"	10 YR. 5.0"	25 YR. 5.4"	50 YR. 6.1"	100 YR. 7.0"
80	0.89	1.33	2.04	2.89	3.25	3.87	4.69
81	0.94	1.39	2.12	2.98	3.34	3.97	4.80
82	0.99	1.46	2.20	3.08	3.44	4.07	4.91
83	1.06	1.53	2.29	3.17	3.54	4.18	5.02
84	1.12	1.60	2.37	3.27	3.64	4.29	5.14
85	1.18	1.68	2.46	3.37	3.74	4.40	5.26
86	1.24	1.74	2.54	3.46	3.83	4.50	5.36
87	1.31	1.83	2.64	3.57	3.95	4.61	5.48
88	1.38	1.90	2.72	3.66	4.05	4.72	5.58
89	1.46	1.99	2.82	3.77	4.16	4.95	5.83
90	1.53	2.08	2.92	3.88	4.26	4.95	5.83
91	1.61	2.16	3.02	3.99	4.37	5.05	5.94
92	1.69	2.26	3.12	4.09	4.48	5.17	6.06
93	1.78	2.35	3.22	4.20	4.59	5.28	6.17
94	1.87	2.44	3.32	4.30	4.70	5.39	6.28
95	1.97	2.54	3.42	4.41	4.81	5.50	6.40
96	2.07	2.66	3.55	4.54	4.94	5.64	6.53
97	2.17	2.77	3.66	4.66	5.06	5.75	6.65
98	2.27	2.87	3.77	4.77	5.17	5.87	6.77

Reference: "SCS-TR-55"

TABULAR DISCHARGES FOR TYPE II STORM DISTRIBUTIONS
CSM/INCH

TIME OF CONCENTRATION = 0.1 hours
Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	24	51	299	991	746	477	233	152	132	121	111	85	74	70	68	65	52	48	39	33	29	24	18	14
0.25	20	38	66	140	327	626	686	546	364	236	169	137	117	97	83	75	66	52	41	35	30	24	18	14
0.50	15	27	36	43	67	133	288	482	580	543	429	310	222	168	134	110	81	63	47	38	32	26	19	15
0.75	12	20	25	29	34	42	65	125	245	392	496	515	452	360	273	206	127	80	53	42	35	27	19	15
1.00	9	15	19	21	24	28	32	41	63	115	209	328	427	470	451	389	245	121	64	47	38	29	20	16
1.50	6	10	12	13	14	16	17	19	22	25	29	38	56	92	154	236	410	360	133	66	47	33	21	16
2.00	3	6	7	8	9	10	11	12	13	14	16	18	20	23	27	34	74	244	371	142	68	38	23	17
2.50	2	4	4	5	5	6	7	7	8	9	10	11	12	13	15	16	21	41	243	343	150	48	26	19
3.00	1	2	2	3	3	4	4	4	5	5	6	7	7	8	9	10	12	17	50	239	321	74	29	20
3.50	0	1	1	1	1	2	2	2	3	3	4	4	4	5	6	6	7	10	17	59	304	159	33	21
4.00	0	0	0	0	0	1	1	1	1	2	2	2	2	3	3	4	5	6	10	18	67	298	39	23

TIME OF CONCENTRATION = 0.2 hours
Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	23	47	208	509	796	641	424	245	170	138	121	104	85	75	71	68	56	49	40	34	29	24	18	14
0.25	18	34	49	91	196	419	603	627	486	341	235	173	138	114	96	83	70	55	43	36	31	25	18	15
0.50	14	24	32	37	50	87	181	341	490	545	497	397	296	219	167	133	92	67	49	39	33	26	19	15
0.75	11	18	23	26	30	36	49	84	161	284	409	491	481	422	340	263	157	89	56	43	36	27	19	15
1.00	9	14	18	20	22	25	29	35	48	79	143	240	347	426	452	427	299	147	69	49	39	29	20	16
1.50	5	9	11	12	13	14	16	18	20	23	26	32	43	67	110	176	330	399	159	72	50	33	22	17
2.00	3	6	7	7	8	9	10	11	12	13	15	16	18	21	24	29	56	192	363	168	75	40	24	18
2.50	1	3	4	5	5	6	6	7	7	8	9	10	11	12	13	15	19	33	200	337	174	51	26	19
3.00	0	2	2	2	3	3	4	4	5	5	6	6	7	8	8	9	11	15	40	203	316	82	29	20
3.50	0	0	1	1	1	2	2	2	2	3	3	4	4	5	5	6	7	9	16	46	300	180	34	22
4.00	0	0	0	0	0	1	1	1	1	1	2	2	2	3	3	3	4	6	9	16	53	286	41	24

TIME OF CONCENTRATION = 0.3 hours
Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	21	43	141	324	586	658	535	372	251	184	148	124	102	86	77	71	61	51	41	34	30	24	18	14
0.25	17	31	43	67	134	279	461	559	530	428	318	234	179	143	116	97	76	59	45	37	32	25	18	15
0.50	13	22	29	34	42	65	124	238	318	479	499	447	363	281	216	168	110	74	51	41	34	26	19	15
0.75	10	17	21	24	27	32	41	63	114	203	316	413	457	443	389	319	198	105	60	45	37	28	20	15
1.00	8	13	16	18	20	23	26	31	40	60	103	176	269	358	415	426	344	182	77	51	41	30	20	16
1.50	5	8	10	11	12	13	15	16	18	21	24	28	36	52	82	132	272	382	192	81	52	34	22	17
2.00	3	5	6	7	8	8	9	10	11	12	14	15	17	19	21	25	44	151	351	198	85	41	24	18
2.50	1	3	4	4	5	5	6	6	7	8	8	9	10	11	12	14	17	28	162	328	200	54	27	19
3.00	0	1	2	2	3	3	3	4	4	5	5	6	6	7	8	9	10	14	33	169	309	94	30	20
3.50	0	0	1	1	1	1	2	2	2	3	3	3	4	4	5	5	6	9	14	38	172	294	35	22
4.00	0	0	0	0	0	0	1	1	1	1	1	2	2	2	3	3	4	5	9	15	43	281	42	24

TIME OF CONCENTRATION = 0.4 hours
Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	20	39	103	224	419	558	575	451	331	247	190	155	127	105	90	80	66	53	42	35	30	24	18	14
0.25	15	28	38	54	98	196	343	467	508	464	380	295	228	180	145	119	87	64	47	38	32	26	19	15
0.50	12	20	26	30	37	53	92	172	286	395	462	453	402	332	266	211	137	84	54	42	35	27	19	15
0.75	10	16	19	22	25	29	36	51	85	150	242	338	407	429	406	356	241	128	65	47	38	29	20	16
1.00	8	12	15	17	19	21	24	28	34	49	78	132	208	292	362	403	368	220	88	55	42	30	21	16
1.50	5	8	9	10	11	12	14	15	17	19	22	25	31	43	65	102	220	365	224	93	56	35	22	17
2.00	3	5	6	6	7	8	9	9	10	11	13	14	16	17	20	23	37	119	338	225	97	43	24	18
2.50	1	3	3	4	4	5	5	6	6	7	8	9	10	11	12	13	16	25	132	317	225	58	27	19
3.00	0	1	2	2	2	3	3	3	4	4	5	5	6	7	7	8	10	13	28	140	300	107	31	21
3.50	0	0	1	1	1	1	1	2	2	2	3	3	3	4	4	5	6	8	13	32	146	286	36	22
4.00	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	3	3	5	8	14	36	275	44	24

TIME OF CONCENTRATION = 0.5 hours
Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	18	36	80	166	301	433	496	474	395	309	242	194	158	130	109	94	75	57	43	36	31	25	18	15
0.25	15	26	31	52	94	172	277	312	425	424	383	326	270	221	182	150	107	73	49	39	33	26	19	15
0.50	12	20	25	30	38	58	101	169	252	327	374	385	366	329	285	241	169	103	59	44	36	27	19	15
0.75	9	15	19	22	25	30	41	63	103	162	229	292	335	354	348	325	255	157	77	50	39	29	20	16
1.00	7	12	15	17	19	21	25	31	43	66	103	153	210	264	304	327	317	231	109	61	44	31	21	16
1.50	5	8	9	10	11	12	14	15	17	20	24	31	43	63	92	129	214	295	224	115	65	36	23	17
2.00	3	5	6	6	7	8	9	10	11	12	13	14	16	19	23	30	58	143	271	216	120	46	25	18
2.50	1	3	3	4	4	5	5	6	7	7	8	9	10	11	12	14	18	39	150	253	209	71	28	19
3.00	0	1	2	2	2	3	3	4	4	4	5	5	6	7	7	8	10	15	48	154	239	126	32	21
3.50	0	0	1	1	1	1	2	2	2	2	3	3	4	4	5	5	6	8	16	56	155	227	38	23
4.00	0	0	0	0	0	1	1	1	1	1	1	2	2	2	3	3	4	5	9	19	63	217	52	25

TIME OF CONCENTRATION = 0.75 hours
Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	15	29	57	98	163	248	329	375	388	369	325	276	232	195	165	142	107	76	51	39	33	26	19	15
0.25	12	21	29	39	61	100	158	227	291	336	355	348	321	285	247	212	156	103	62	44	36	27	19	15
0.50	10	16	21	24	29	41	63	100	150	208	263	305	327	329	314	288	226	147	79	52	40	29	20	16
0.75	8	13	16	18	20	24	30	43	65	98	142	192	239	278	303	311	286	208	107	63	45	31	21	16
1.00	6	10	13	14	15	17	20	24	31	44	65	95	134	177	220	256	294	264	149	81	53	33	21	16
1.50	4	6	8	9	10	11	12	13	14	16	19	23	31	42	60	83	147	269	248	152	85	40	23	17
2.00	2	4	5	5	6	7	7	8	9	10	11	12	14	16	18	23	39	97	251	235	153	56	26	19
2.50	1	2	3	3	4	4	4	5	5	6	7	7	8	9	10	11	15	28	107	218	236	91	29	20
3.00	0	1	1	2	2	2	2	3	3	4	4	5	5	6	6	7	8	12	33	113	225	153	34	22
3.50	0	0	1	1	1	1	1	1	2	2	2	3	3	3	4	4	5	7	13	39	117	215	44	24
4.00	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	3	4	7	15	45	207	63	26

TIME OF CONCENTRATION = 1.0 hours
Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	13	24	45	66	107	155	211	258	301	313	316	301	277	247	217	188	146	102	64	46	36	27	19	15
0.25	10	18	24	32	45	68	102	146	193	238	272	293	299	293	275	252	200	139	81	54	41	29	20	16
0.50	8	14	17	20	24	32	46	68	99	136	178	219	251	274	284	283	254	187	105	65	47	31	21	16
0.75	7	11	13	15	17	20	25	33	46	67	94	128	165	202	233	256	273	236	140	82	55	33	21	16
1.00	5	9	11	12	13	15	17	20	25	33	46	65	90	121	154	187	240	262	183	107	66	37	22	17
1.50	3	5	7	7	8	9	10	11	12	14	16	19	24	31	43	58	103	185	244	181	110	48	24	18
2.00	2	3	4	4	5	6	6	7	8	8	9	10	11	13	15	18	29	69	182	230	178	70	27	19
2.50	1	2	2	3	3	3	4	4	5	5	6	6	7	8	9	10	12	21	77	178	219	114	31	21
3.00	0	1	1	1	1	2	2	2	3	3	3	4	4	5	5	6	7	10	25	83	210	172	39	22
3.50	0	0	0	0	1	1	1	1	1	2	2	2	2	3	3	3	4	6	11	29	88	202	52	25
4.00	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	4	6	12	33	195	77	28

TIME OF CONCENTRATION = 1.25 hours
Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	11	21	37	51	79	107	147	187	219	249	264	271	267	256	241	219	177	128	81	56	42	29	20	16
0.25	9	15	21	27	36	53	74	103	137	172	205	231	249	259	259	253	223	167	102	67	48	31	21	16
0.50	7	12	15	17	21	27	37	51	72	98	128	160	190	216	235	247	251	209	130	82	56	34	21	16
0.75	6	9	12	13	15	17	21	27	36	50	69	93	120	149	177	202	235	242	165	103	67	38	22	17
1.00	4	7	9	10	11	13	14	17	21	27	36	49	66	88	113	139	190	236	200	130	83	43	23	17
1.50	3	5	6	6	7	8	8	9	10	12	14	16	20	25	33	44	76	142	223	195	131	58	26	18
2.00	1	3	3	4	4	5	5	6	6	7	8	9	10	11	13	15	24	52	143	212	189	86	29	20
2.50	1	1	2	2	2	3	3	3	4	4	5	5	6	7	7	8	10	17	58	143	201	132	35	21
3.00	0	1	1	1	1	1	2	2	2	2	3	3	3	4	4	5	6	9	20	64	143	196	45	23
3.50	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	3	4	5	9	23	68	190	62	26
4.00	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	3	5	10	26	184	91	30

TIME OF CONCENTRATION = 1.5 hours

Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	10	18	31	42	57	81	105	133	164	192	209	227	235	236	236	225	201	153	99	68	50	32	20	16
0.25	8	13	17	22	30	41	57	76	99	125	153	178	199	215	225	230	224	188	122	82	58	36	21	16
0.50	6	10	13	15	18	22	30	40	54	72	94	118	143	167	188	204	224	214	152	99	68	39	22	17
0.75	5	8	10	11	13	15	18	22	29	30	52	69	89	111	134	157	194	219	182	122	82	44	23	17
1.00	4	6	8	9	10	11	12	14	17	22	29	38	50	66	84	105	148	198	214	150	100	50	24	18
1.50	2	4	5	5	6	7	7	8	9	10	12	14	17	21	26	34	58	109	191	204	149	70	28	19
2.00	1	2	3	3	4	4	4	5	5	6	7	8	8	10	11	13	19	40	112	184	197	102	33	20
2.50	0	1	1	2	2	2	3	3	3	4	4	5	5	6	6	7	9	14	45	114	190	147	40	22
3.00	0	0	1	1	1	1	1	1	2	2	2	3	3	3	4	4	5	7	16	49	115	184	53	25
3.50	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	2	3	4	8	18	53	178	74	28
4.00	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	4	8	21	174	105	34

TIME OF CONCENTRATION = 2.0 hours

Hydrograph Time in Hours

T_t	11.0	11.5	11.7	11.8	11.9	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.2	13.5	14.0	14.5	15.0	16.0	18.0	20.0
0	7	14	22	30	38	49	64	80	95	114	133	152	165	175	184	192	190	176	129	93	68	41	23	17
0.25	6	10	13	17	22	28	37	47	61	75	91	108	126	143	157	168	185	189	153	109	79	46	24	17
0.50	5	8	10	11	13	17	21	27	35	45	57	71	86	103	119	135	162	186	172	129	92	52	26	18
0.75	4	6	8	8	10	11	13	16	21	26	34	43	55	67	82	97	129	166	183	149	109	59	27	18
1.00	3	5	6	7	7	8	9	11	13	16	20	26	33	42	52	64	92	136	180	167	127	68	29	19
1.50	1	3	3	4	4	5	5	6	7	8	9	10	12	15	18	23	37	68	135	175	163	93	34	21
2.00	1	1	2	2	3	3	3	4	4	5	5	6	6	7	8	10	14	26	71	133	170	127	42	23
2.50	0	1	1	1	1	1	2	2	2	3	3	3	4	4	5	5	7	11	29	74	132	166	53	26
3.00	0	0	0	0	1	1	1	1	1	1	2	2	2	2	3	3	4	5	12	32	76	162	71	30
3.50	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2	3	6	13	35	158	95	35
4.00	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	2	3	6	14	80	155	43

Gutters, Ditches and Channels	Value of "n"
Concrete or bituminous lined channels	0.013
Bituminous concrete paving with concrete gutter	0.015
Grass gutters & ditches, flow greater than 6"	.040
Grass gutters & ditches, flow less than 6"	.060
Gabions	0.030
Rip-Rap	Ref. to Chart SHA-61.1-405.1
Channels not maintained, uncut weeds & brush	.08 - .12
Earth gutters and ditches	.025
Ditches in rock	.037
Seed and Mulch	.030
Soil Stabilization Matting	.030
Natural Stream channels	.035 - .150

ENTRANCE LOSS COEFFICIENTS

Type of Structure and Design of Entrance	Coefficient K_e
Pipe, Concrete	
Projecting from fill, socket end (groove-end)	0.2
Projecting from fill, sq. cut end	0.5
Headwall or headwall and wingwalls	
Socket end of pipe (groove-end)	0.2
Square-edge	0.5
Rounded (radius = 1/12D)	0.2
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Pipe or Pipe-Arch, Corrugated Metal	
Projecting from fill, (no headwall)	0.9
Headwall or headwall and wingalls	
Square-edge	0.5
Mitered to conform to fill slope	0.7
*End-Section conforming to fill slope	0.5
Box, Reinforced Concrete	
Headwall parallel to embankment (no wingwalls)	
Square-edged on 3 edges	0.5
Rounded on 3 edges to radius of 1/12 barrell dimension	0.2
Wingwalls at 30 to 75 to barrell	
Square-edged at crown	0.4
Crown edge rounded to radius of 1/12 barrell dimension	0.2
Wingwalls at 10 to 25 to barrell	
Square-edged at crown	0.5
Wingwalls parallel (extension of sides)	
Square-edged at crown	0.7

*NOTE: "End Section conforming to fill slope," made of either metal or concrete, are the sections commonly available from manufacturers. From limited hydraulic tests they are equivalent in operation to headwall in both inlet and outlet control.

LIMITING VELOCITIES FOR DITCHES AND CHANNELS

Type of Lining	Allowable velocity Feet per second
Earth, without vegetation	1-3
Seed and Mulch	2.5
Grains, stiff stemmed grasses	2-3
Bunch grass	2-4
Solid Sodding	4
Stiff clay or clay and gravel	3-5
Fine gravel	5
Well-established grasses, short pliant blades	5
Soil Stabilization matting over seed and mulch	5
Shale and Rock	5.6
Course gravel	6
Riprap	Refer to Chart SHA 61.1-405.1
Concrete Channel	No Max.

USE SOIL STABILIZATION MATTING OVER SEED AND MULCH FOR CONSTRUCTION ITEMS

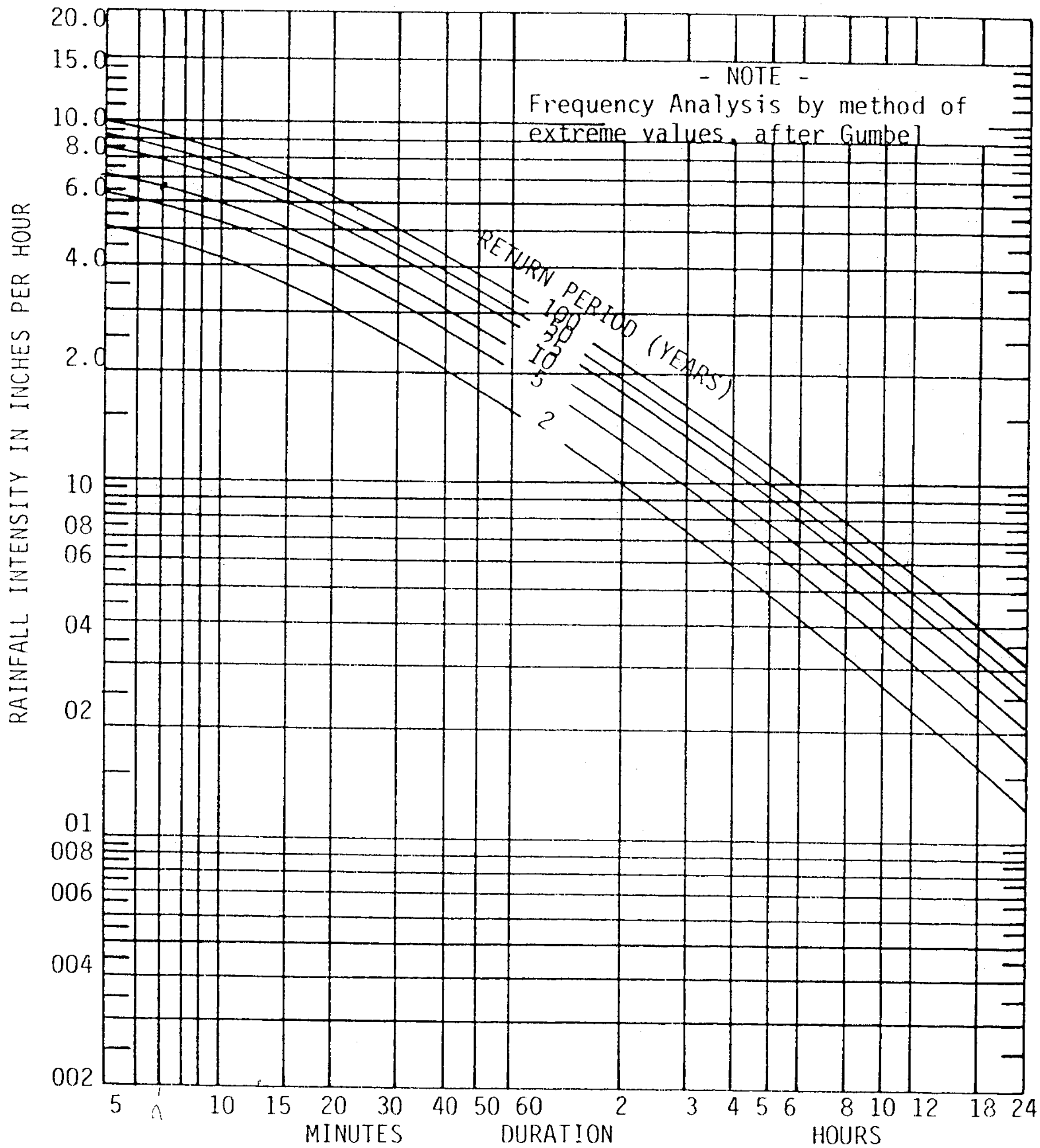
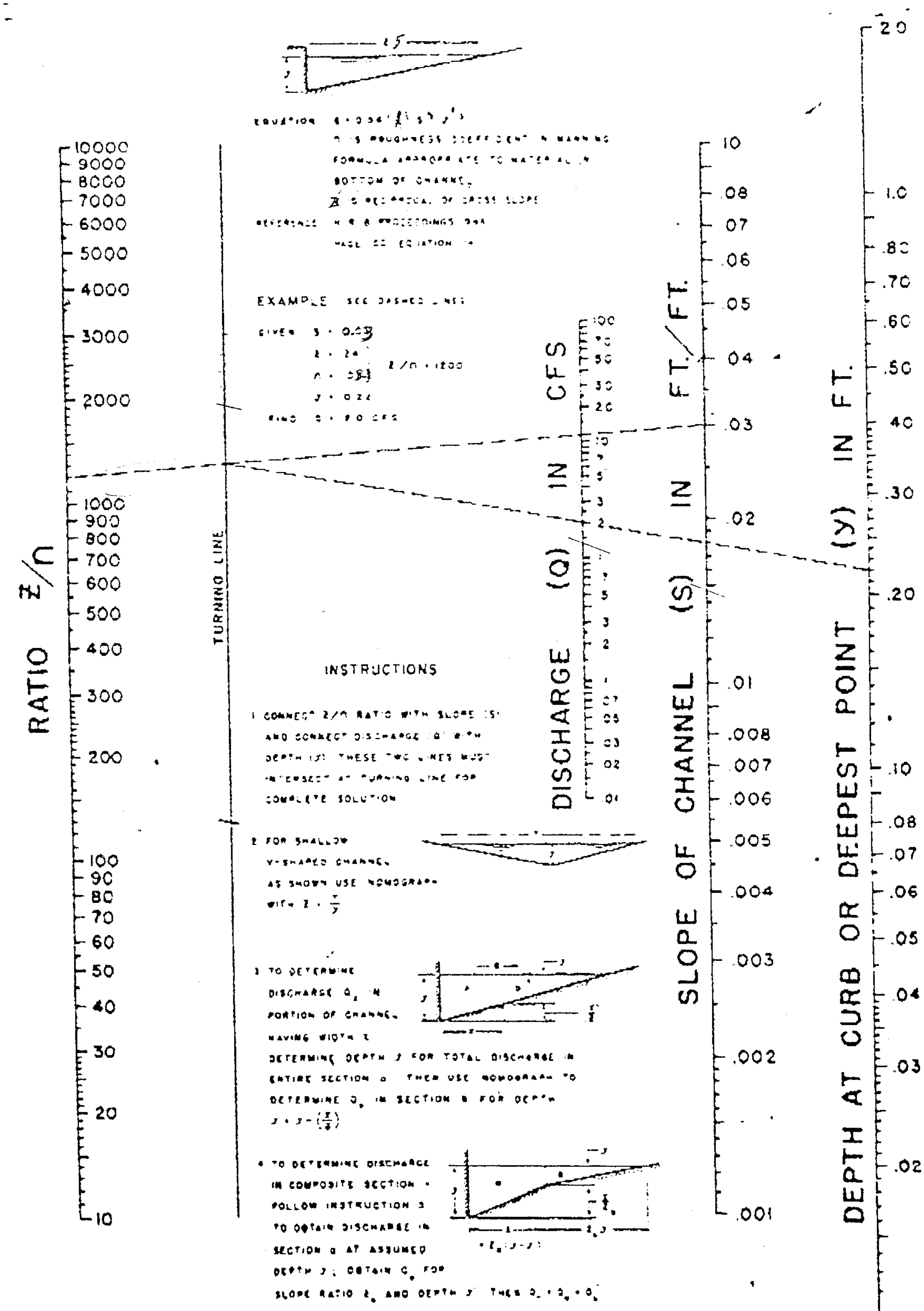


Exhibit 4.19

INTENSITY DURATION FREQUENCY CURVES



NOMOGRAPH FOR FLOW IN TRIANGULAR CHANNELS

RUNOFF CURVE NUMBERS

RURAL AREAS

	HYDROLOGIC SOIL GROUP			
	A	B	C	D
Wooded:				
Poor - No mulch, small trees or brush	45	66	77	83
Fair - Grazed, some mulch	36	60	73	79
Good - Protected from grazing, Heavy mulch and shrubs cover soil	25	55	70	77
Pasture: (Native or improved grassland reserved for grazing)				
Poor - Heavily grazed, Plant cover on less than 50% of area	68	79	86	89
Fair - Not heavily grazed, Plant cover on 50% to 75% of area	49	69	79	84
Good - Lightly grazed, Plant cover on more than 75% of area	39	61	74	80
Meadow: (Grass grown for hay crop)	30	58	71	78
Cultivated:				
Fallow: (Plowed, no crop planted)	77	86	91	94
Row Crop: (Corn, soybeans, tomatoes, etc. spaced about 3 1/2' apart)	72	81	88	91
Small Grain: (Wheat, oats, barley, etc.)	65	76	84	88
Water Surfaces	100	100	100	100

Source - Ref. #9 Appendix 2

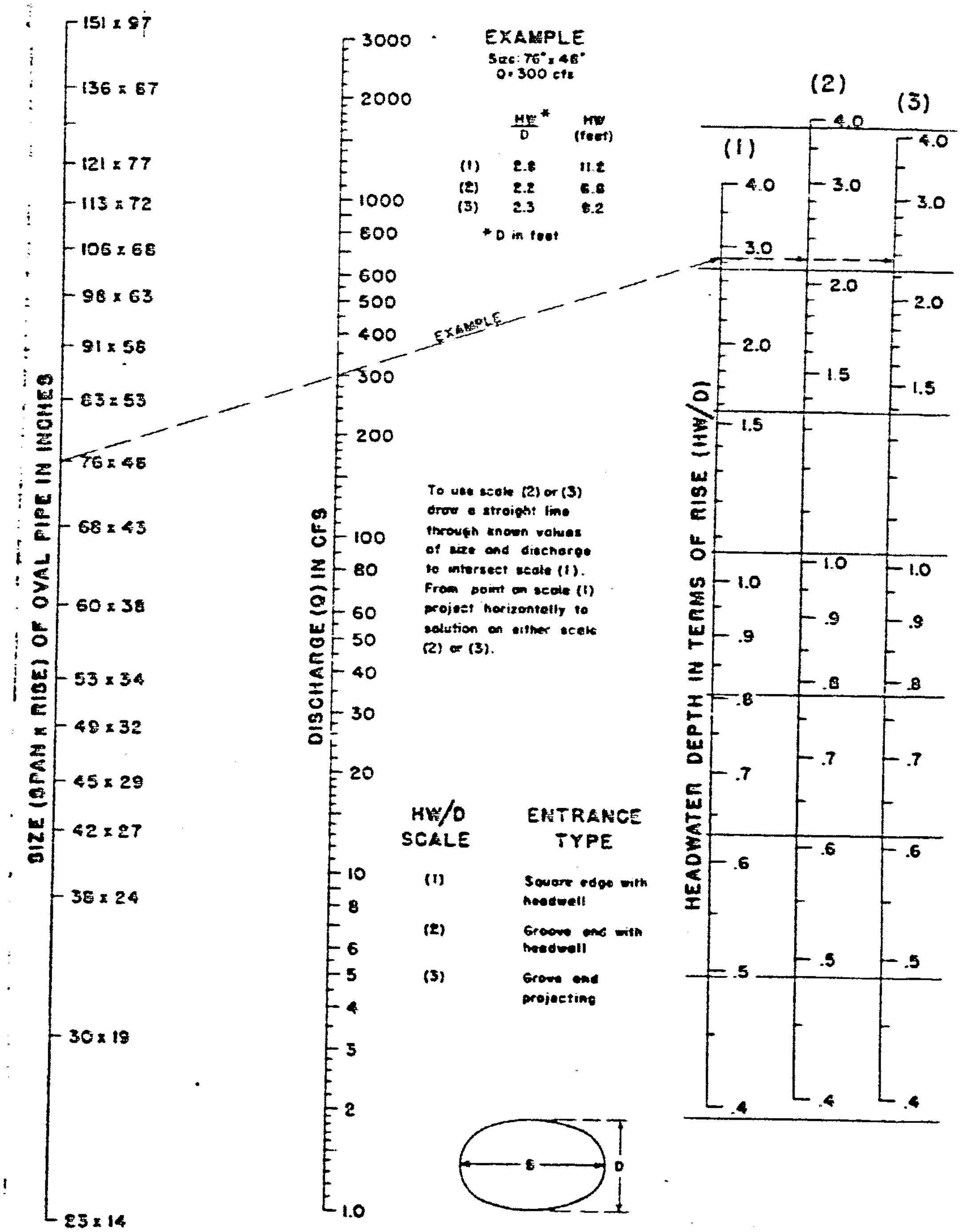
RUNOFF CURVE NUMBERS

URBAN AREAS

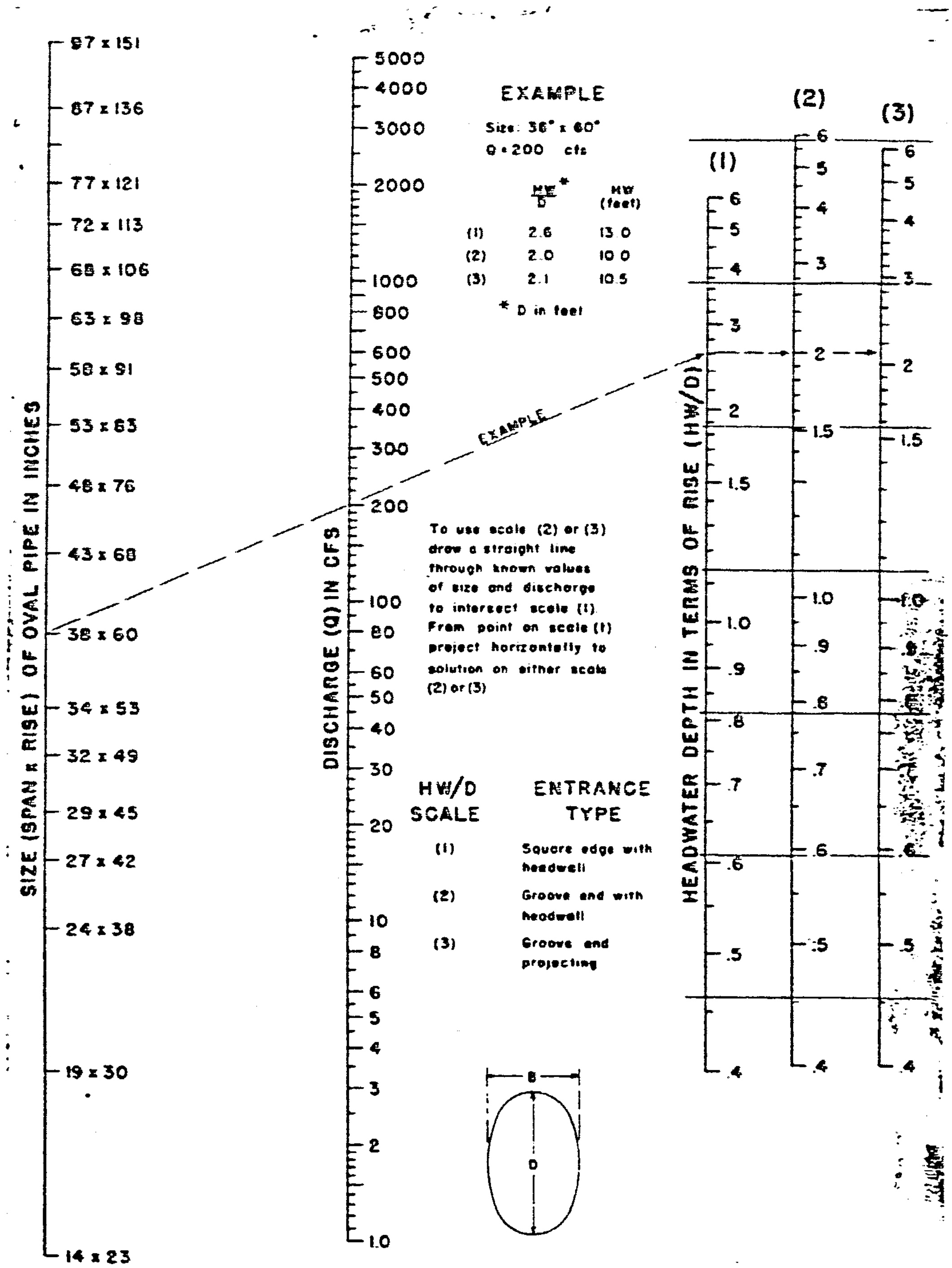
	HYDROLOGIC SOIL GROUP			
	A	B	C	D
Open Spaces, Lawns, Parks, Golf courses, Cemeteries				
Grass covers 75% or more of area	39	61	74	80
Grass covers 50% to 75% or area	49	69	79	84
Paved Areas, Roofs	98	98	98	98
Streets and Roads				
Paved, Curb and Gutter	98	98	98	98
Hard Surfaced (Includes R/W)	74	84	90	92
Gravel	76	85	89	91
Dirt (Includes R/W)	72	82	87	89
Residential Development				
Row Houses or Town Houses	80	85	90	95
1/8 acre lots Average 65% impervious	77	85	90	92
1/4 acre lots Average 38% impervious	61	75	83	87
1/3 acre lots Average 30% impervious	57	72	81	86
1/2 acre lots Average 25% impervious	54	70	80	85
1 acre lots Average 20% impervious	51	68	79	84
2 acre lots	47	66	77	81
Newly Graded area, no vegetation	81	89	93	95
Commercial and Business Areas 85% impervious	89	92	94	95
Industrial Areas 72% impervious	81	88	91	93

Source - Ref. # 26 Appendix 2

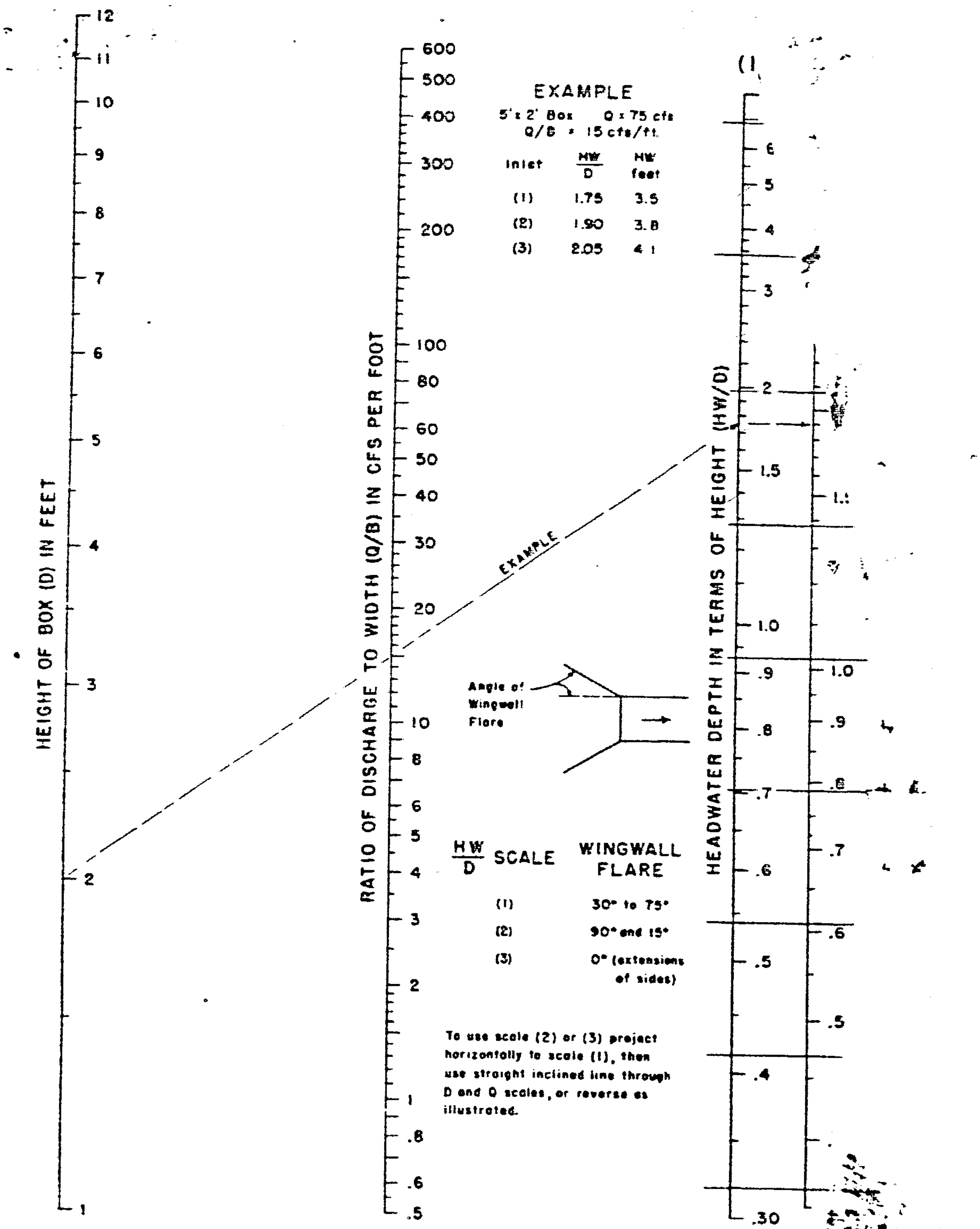
SHA-61.1 401.2B



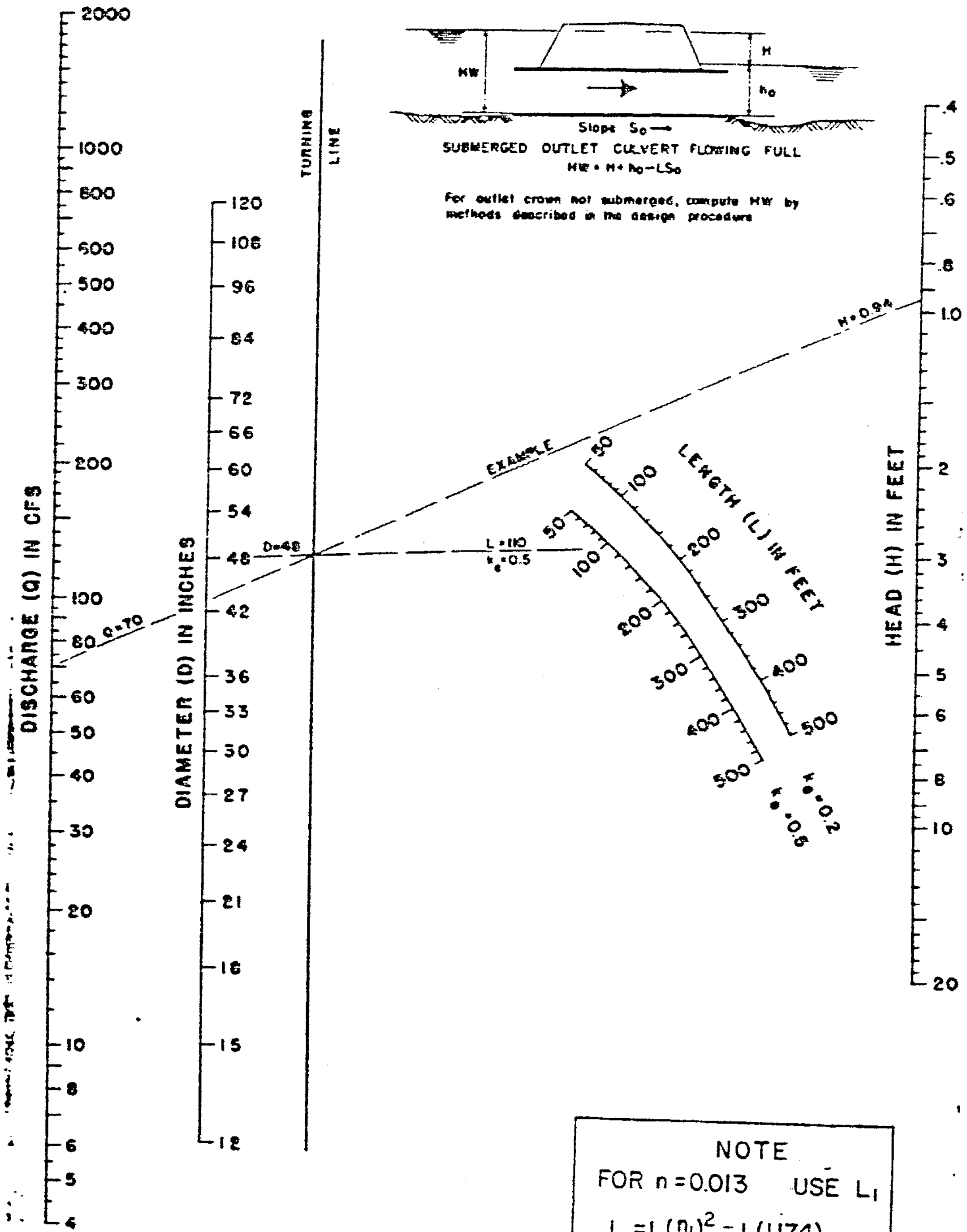
HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL WITH INLET CONTROL



HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS VERTICAL WITH INLET CONTROL



HEADWATER DEP
FOR BOX CULVE
WITH INLET CON

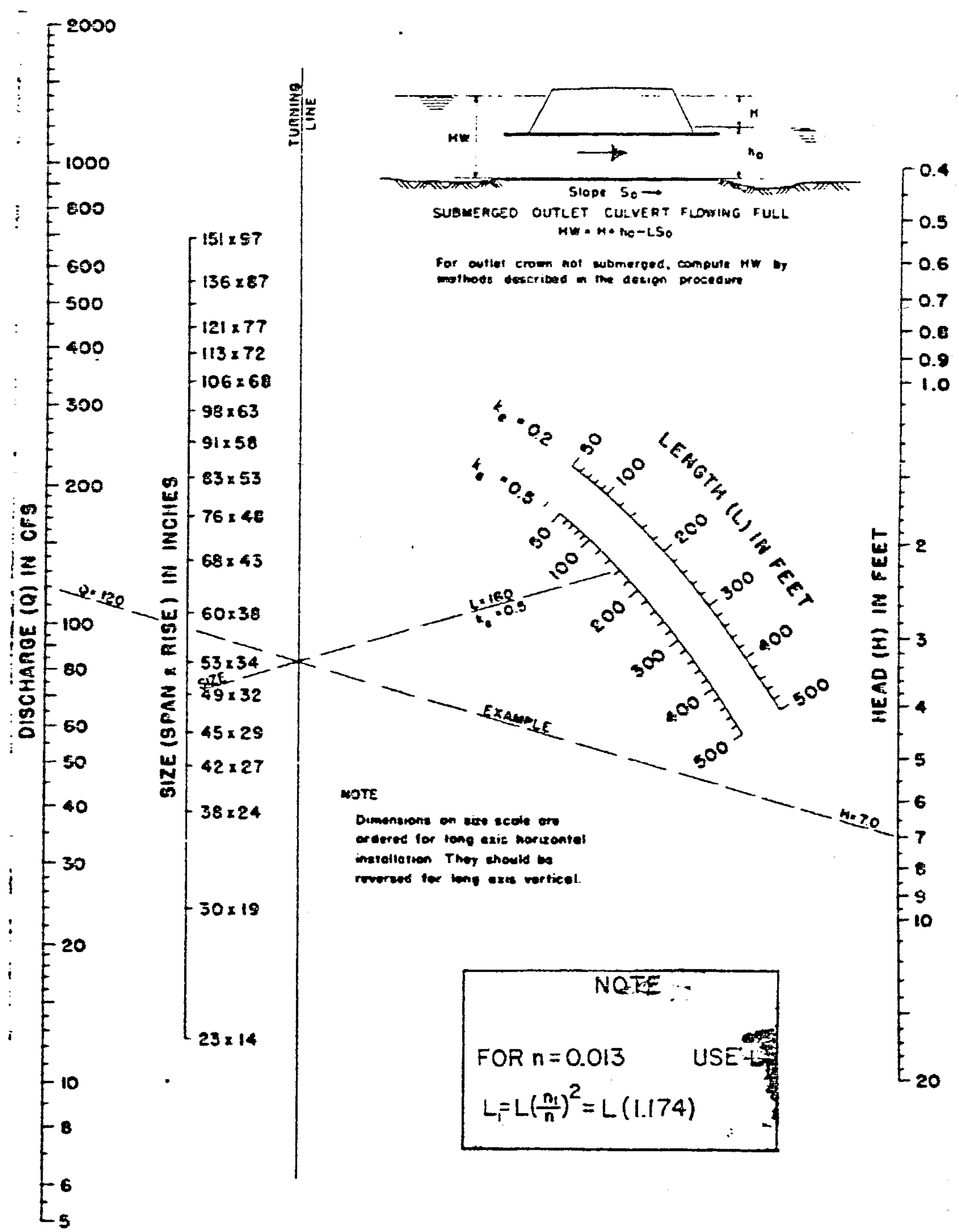


NOTE

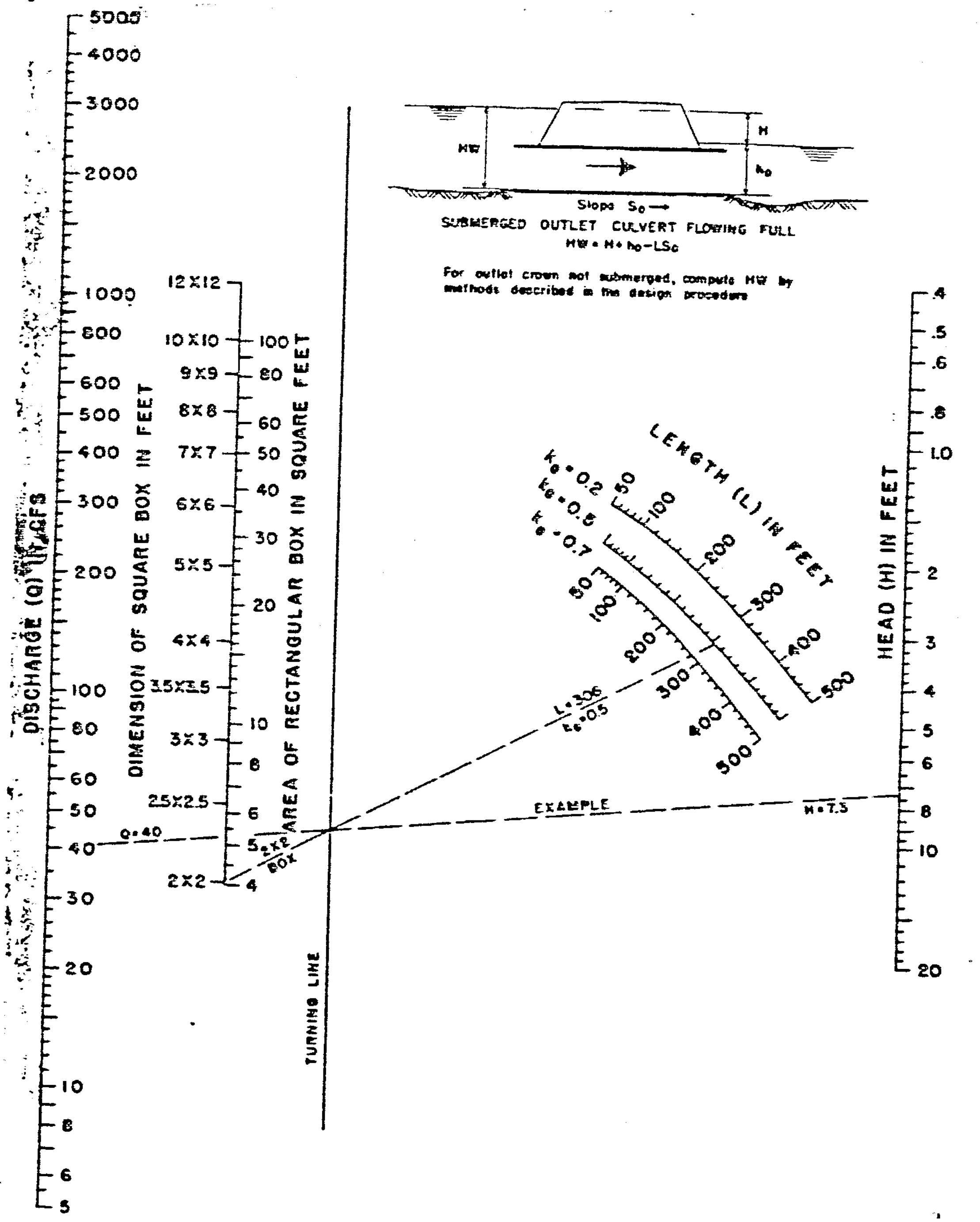
FOR n = 0.013 USE L_1

$L_1 = L(\frac{n_1}{n})^2 = L(1.174)$

HEAD FOR CONCRETE PIPE CULVERTS FLOWING FULL n = 0.012

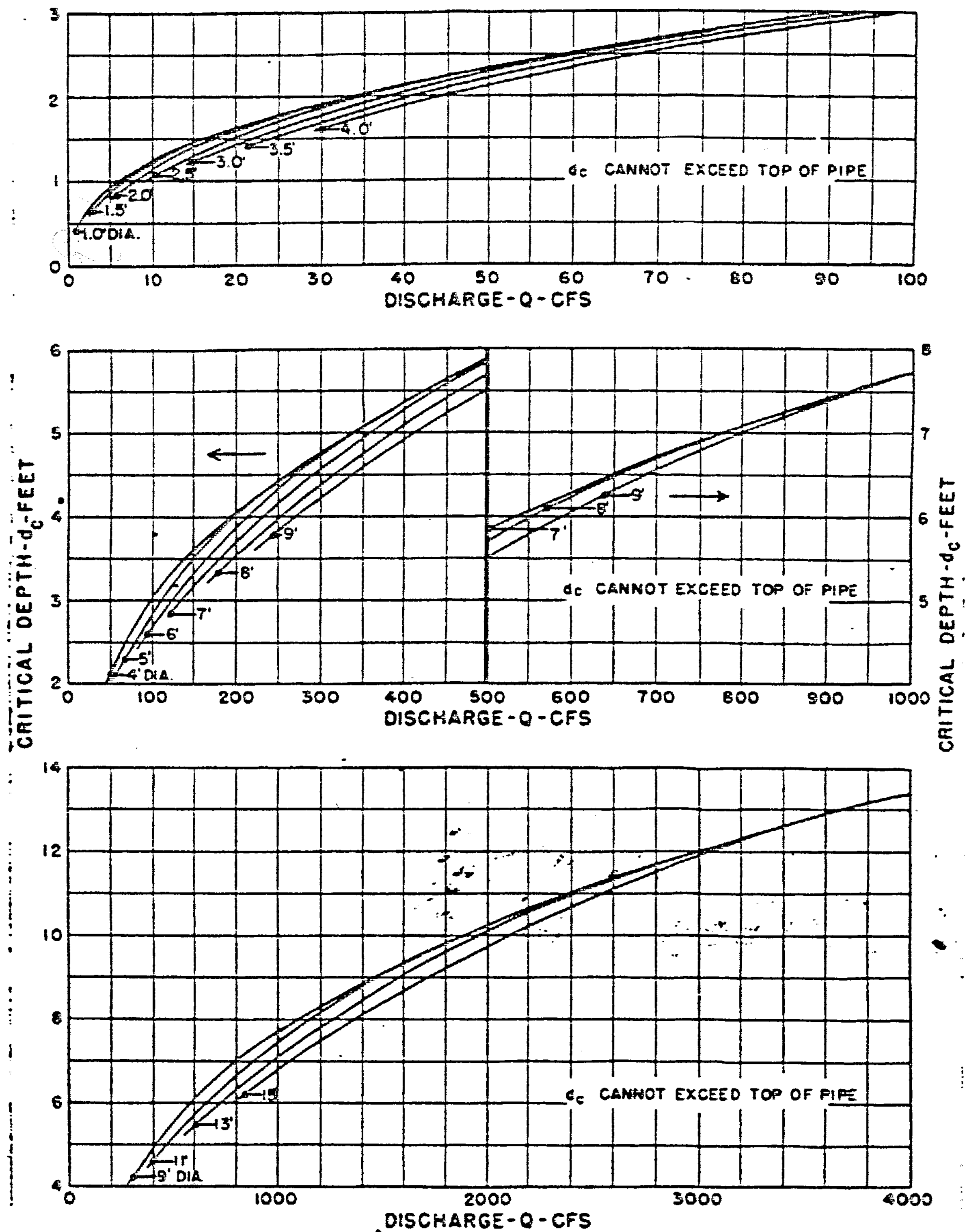


HEAD FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL OR VERTICAL FLOWING FULL $n = 0.012$

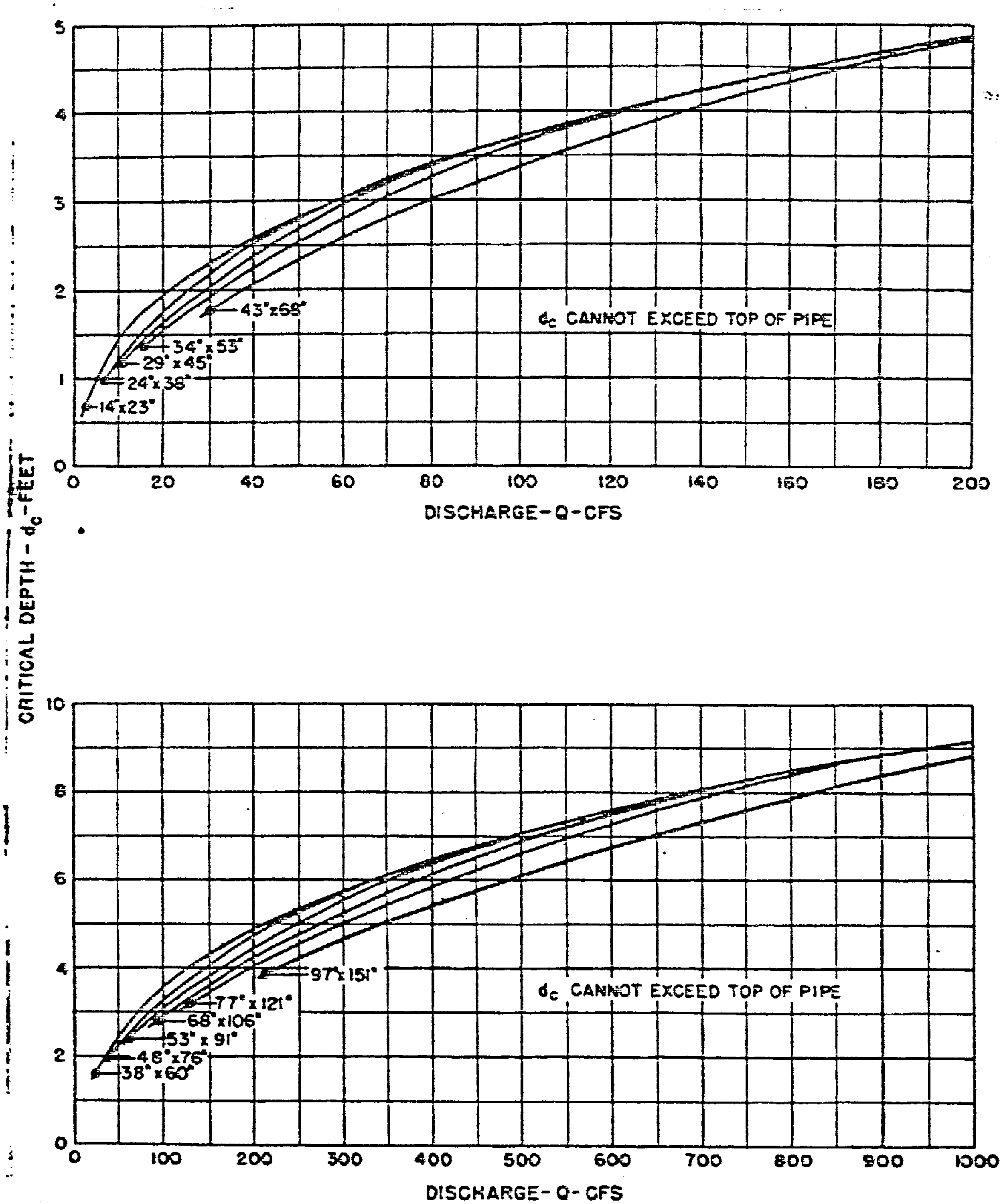


HEAD FOR CONCRETE BOX CULVERTS FLOWING FULL

n = 0.012



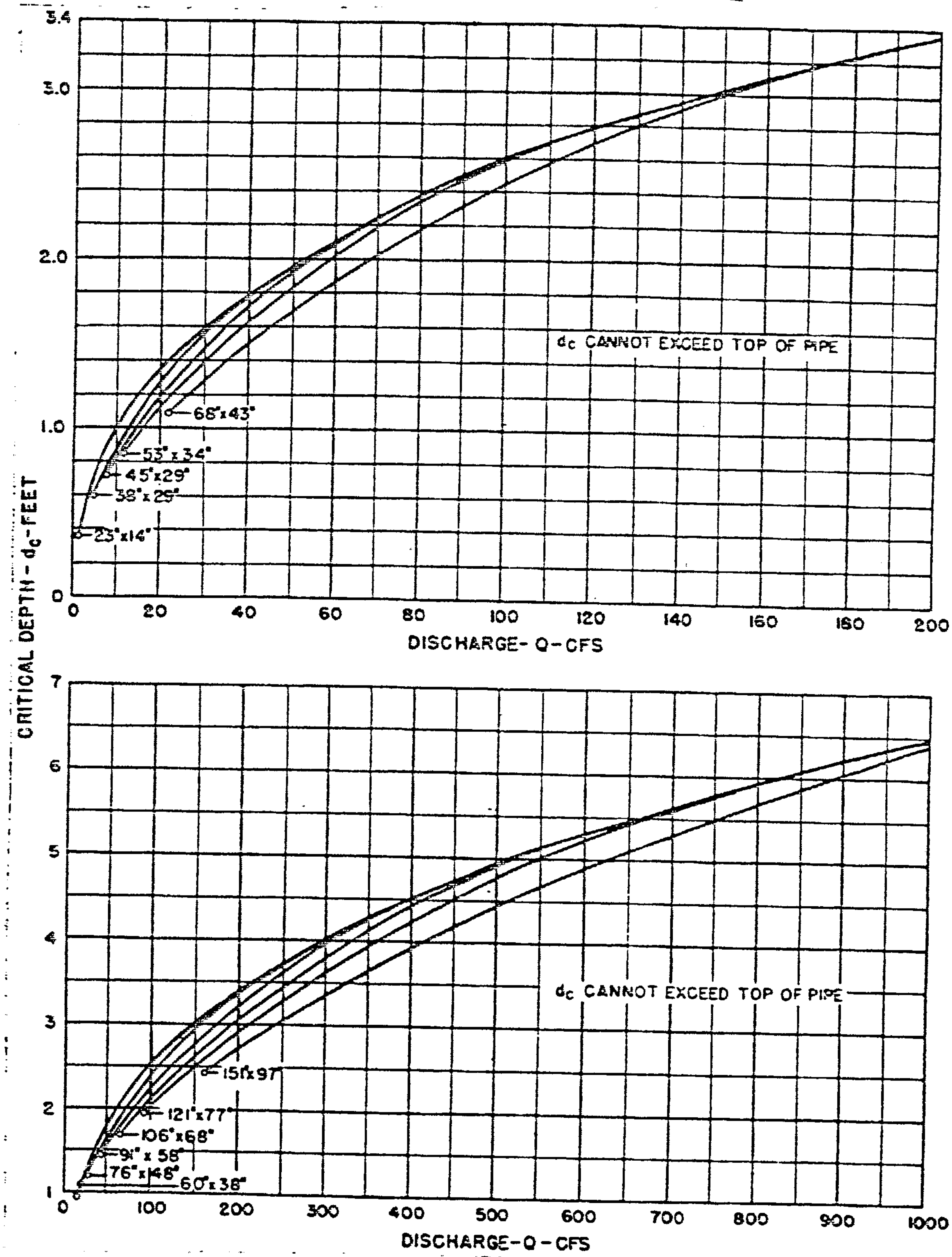
CRITICAL DEPTH
CIRCULAR PIPE



CRITICAL DEPTH
OVAL CONCRETE PIPE
LONG AXIS VERTICAL

SD-A- 25

MARYLAND STATE HIGHWAY ADMINISTRATION 1/64 SHA-61.1-422.3-1.1



CRITICAL DEPTH
OVAL CONCRETE PIPE
LONG AXIS HORIZONTAL

BASIC DATA - CIRCULAR PIPE

SHA-61.1-440.0-1

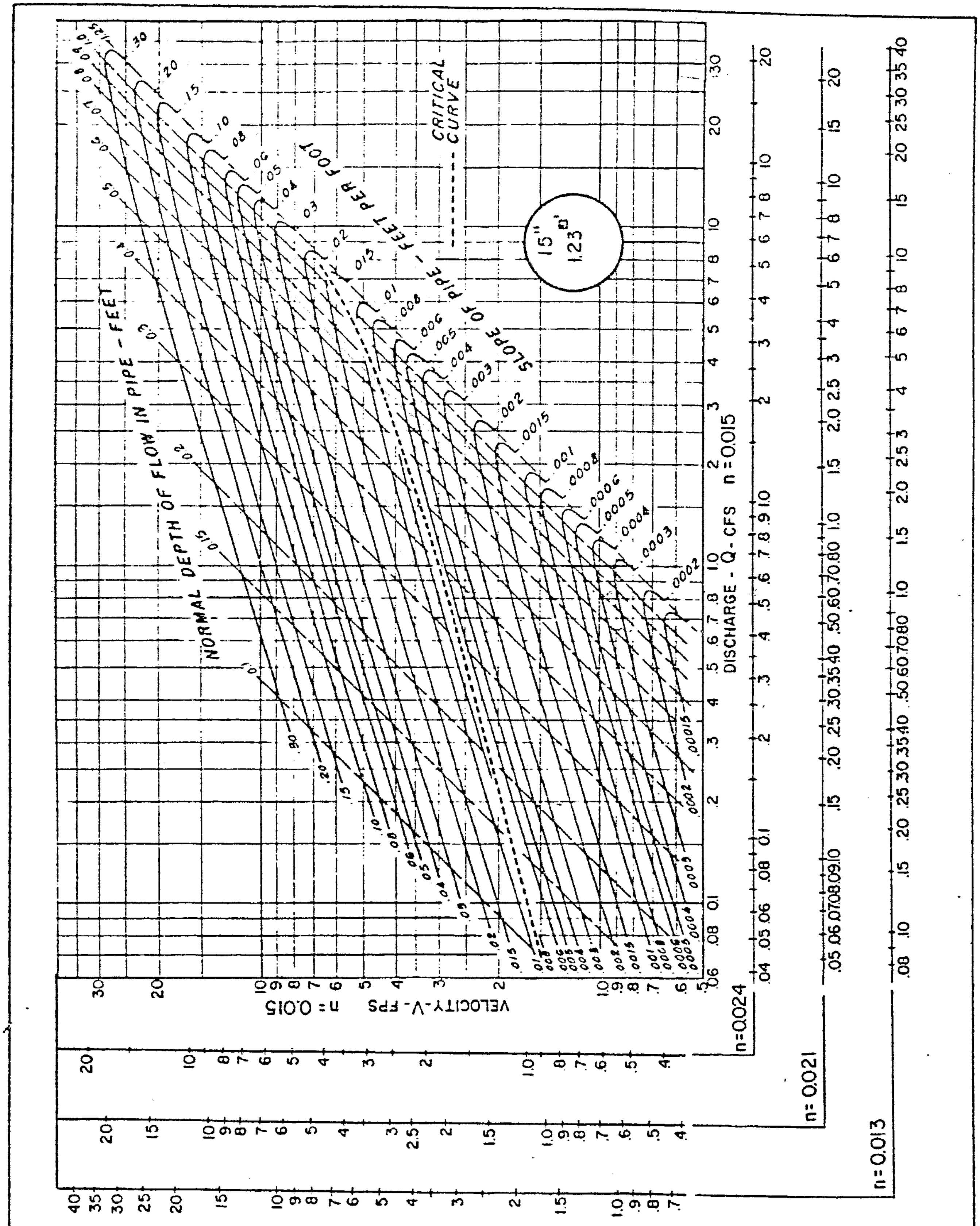
NOMINAL SIZE	INSIDE DIAMETER	AREA	PERIMETER	CONCRETE PIPE MINIMUM WALL THICKNESS — AASHO M-170 CLASS IV OR V — WALL B	CONCRETE PIPE MINIMUM WALL THICKNESS — AASHO M-170 CLASS IV OR V — WALL C	CLASS IV ONLY	REMARKS
INCHES	FEET	SQ. FT.	FEET	INCHES	INCHES	INCHES	
12	1.00	0.79	3.14	2	-		*
15	1.25	1.23	3.93	2 1/4	-		*
18	1.50	1.77	4.71	2 1/2	-		*
21	1.75	2.41	5.50	2 3/4	-		*
24	2.00	3.14	6.28	3	3 3/4		*
27	2.25	3.97	7.07	3 1/4	4		*
30	2.50	4.91	7.85	3 1/2	4 1/4		*
33	2.75	5.94	8.63	3 3/4	4 1/2		*
36	3.00	7.07	9.43	4	4 3/4		*
42	3.50	9.62	11.00	4 1/2	5 1/4		*
48	4.00	12.57	12.57	5	5 3/4		*
54	4.50	15.90	14.14	5 1/2	6 1/4		*
60	5.00	19.64	15.71	6	6 3/4		*
66	5.50	23.76	17.28	6 1/2	7 1/4		*
72	6.00	28.27	18.85	7	7 3/4		*
78	6.50	33.18	20.42	7 1/2	8 1/4*		
84	7.00	38.49	21.99	8	8 3/4*		*
90	7.50	44.18	23.56	8 1/2	9 1/4	8 1/2	
96	8.00	50.27	25.13	9	9 3/4	8 1/2	*
102	8.50	56.75	26.70	9 1/2	10 1/4	9	
108	9.00	63.62	28.27	10	10 3/4	9	
120	10.00	78.54	31.42	-	-	10	
126	10.50	86.59	32.99	-	-	10 1/2	
132	11.00	95.03	34.56	-	-	11	
138	11.50	103.87	35.13	-	-	11 1/2	
144	12.00	113.10	37.70	-	-	12	

* DESIGN CHARTS ARE AVAILABLE FOR THESE PIPE SIZES

BASIC DATA - REINFORCED CONCRETE ELLIPTICAL PIPE SHA-61.1-441.0-1

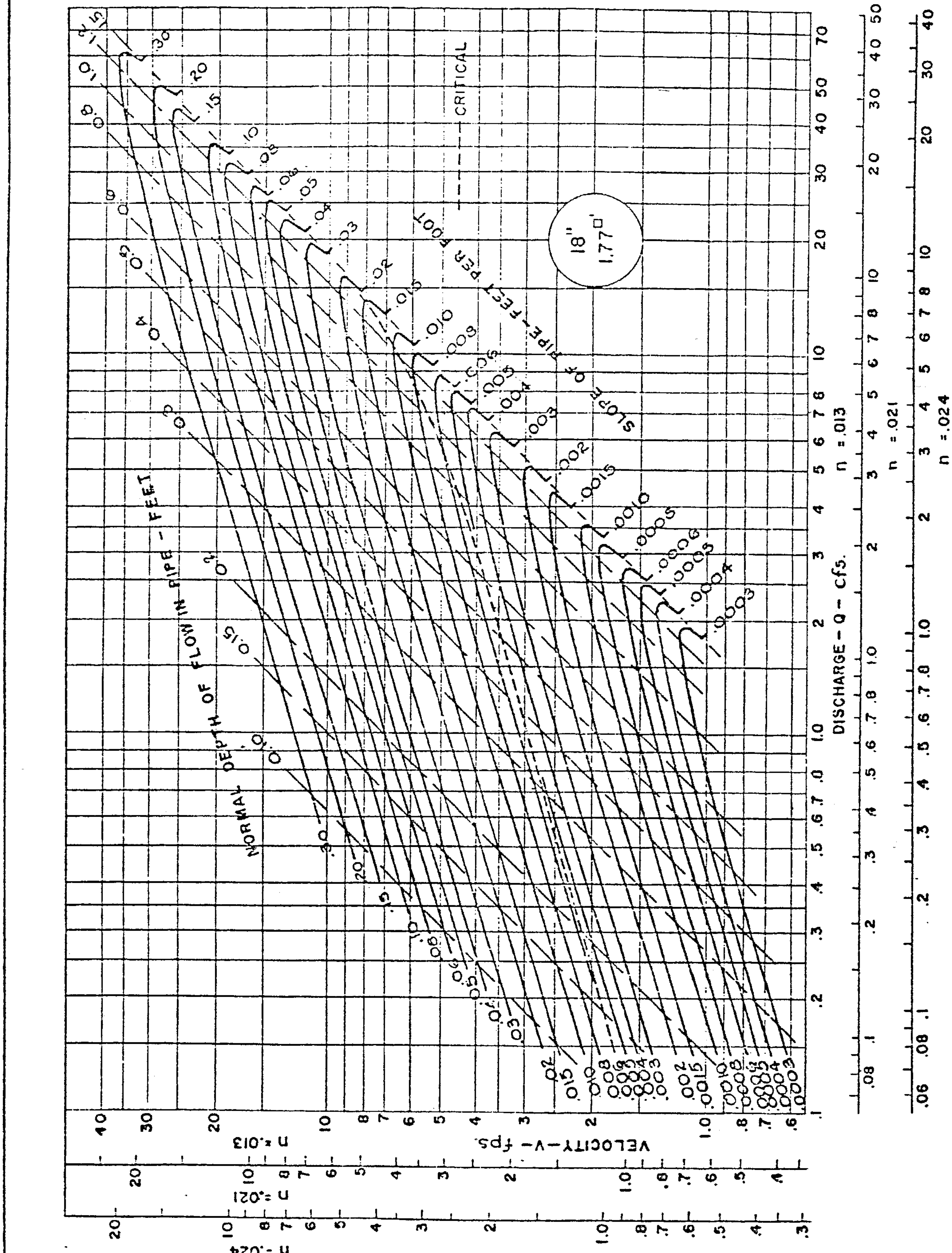
SIZE SPAN x RISE	APPROXIMATE EQUIVALENT ROUND SIZE (DIAMETER)	AREA	PERIMETER	MINIMUM WALL THICKNESS	REMARKS
INCHES	INCHES	SQ. FT.	FEET	INCHES	
23 x 14	18	1.8	4.92	2 3/4	
30 x 19	24	3.3	6.50	3 1/4	*
34 x 22	27	4.1	7.42	3 1/2	*
38 x 24	30	5.1	8.23	3 3/4	*
42 x 27	33	6.3	9.15	3 3/4	*
45 x 29	36	7.4	9.81	4 1/2	*
49 x 32	39	8.8	10.73	4 3/4	*
53 x 34	42	10.2	11.54	5	*
60 x 38	48	12.9	13.00	5 1/2	*
68 x 43	54	16.6	14.73	6	*
76 x 48	60	20.5	16.46	6 1/2	*
83 x 53	66	24.8	18.03	7	*
91 x 58	72	29.5	19.76	7 1/2	*
98 x 63	78	34.6	21.34	8	*
106 x 68	84	40.1	23.07	8 1/2	
113 x 72	90	46.1	24.54	9	
121 x 77	96	52.4	26.26	9 1/2	
128 x 82	102	59.2	27.85	9 3/4	
136 x 87	108	66.4	29.57	10	
143 x 92	114	74.0	31.15	10 1/2	
151 x 97	120	82.0	32.88	11	
106 x 106	132	99.2	36.04	12	
180 x 116	144	118.6	39.24	13	

*DESIGN CHARTS ARE AVAILABLE FOR THESE PIPE SIZES



PIPE FLOW CHART 15- INCH DIAMETER

MARYLAND STATE HIGHWAY ADMINISTRATION 9/78 SHA-61.1-440.15

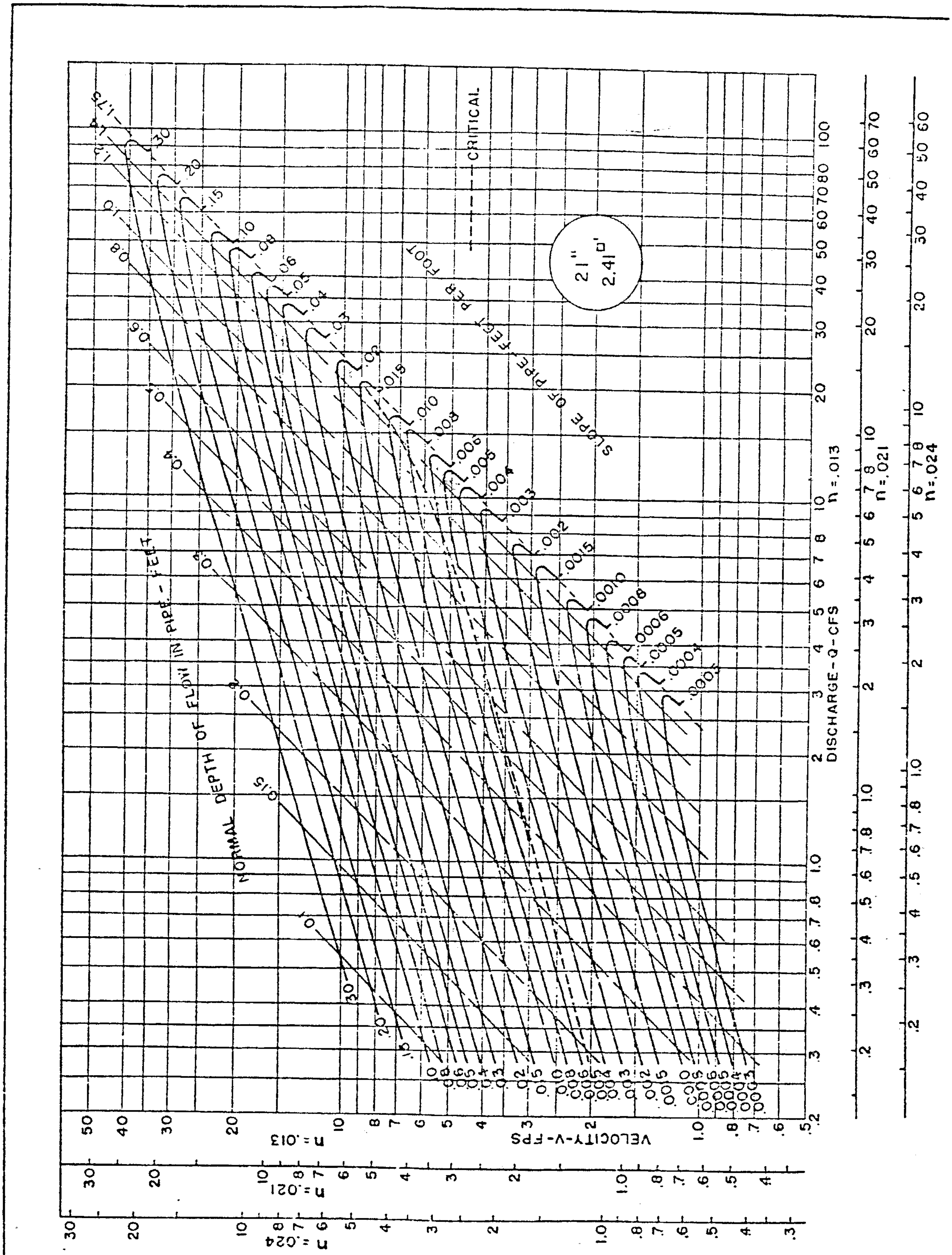


PIPE FLOW CHART 18- INCH DIAMETER

SD-A- 30

IV-3-8-5

MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61.1-440.18

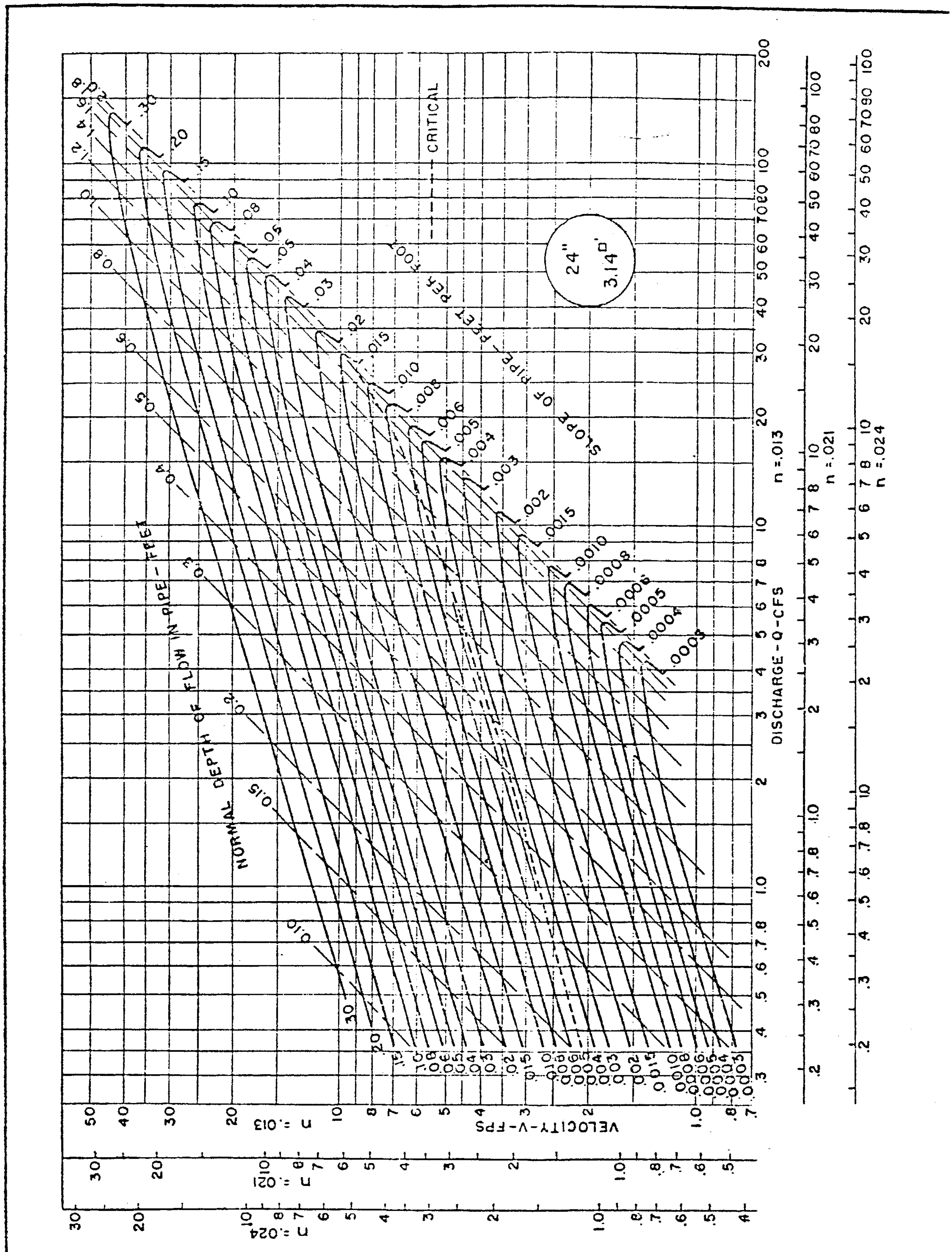


SD-A- 32

PIPE FLOW CHART 21" DIAMETER

IV-3-8-6

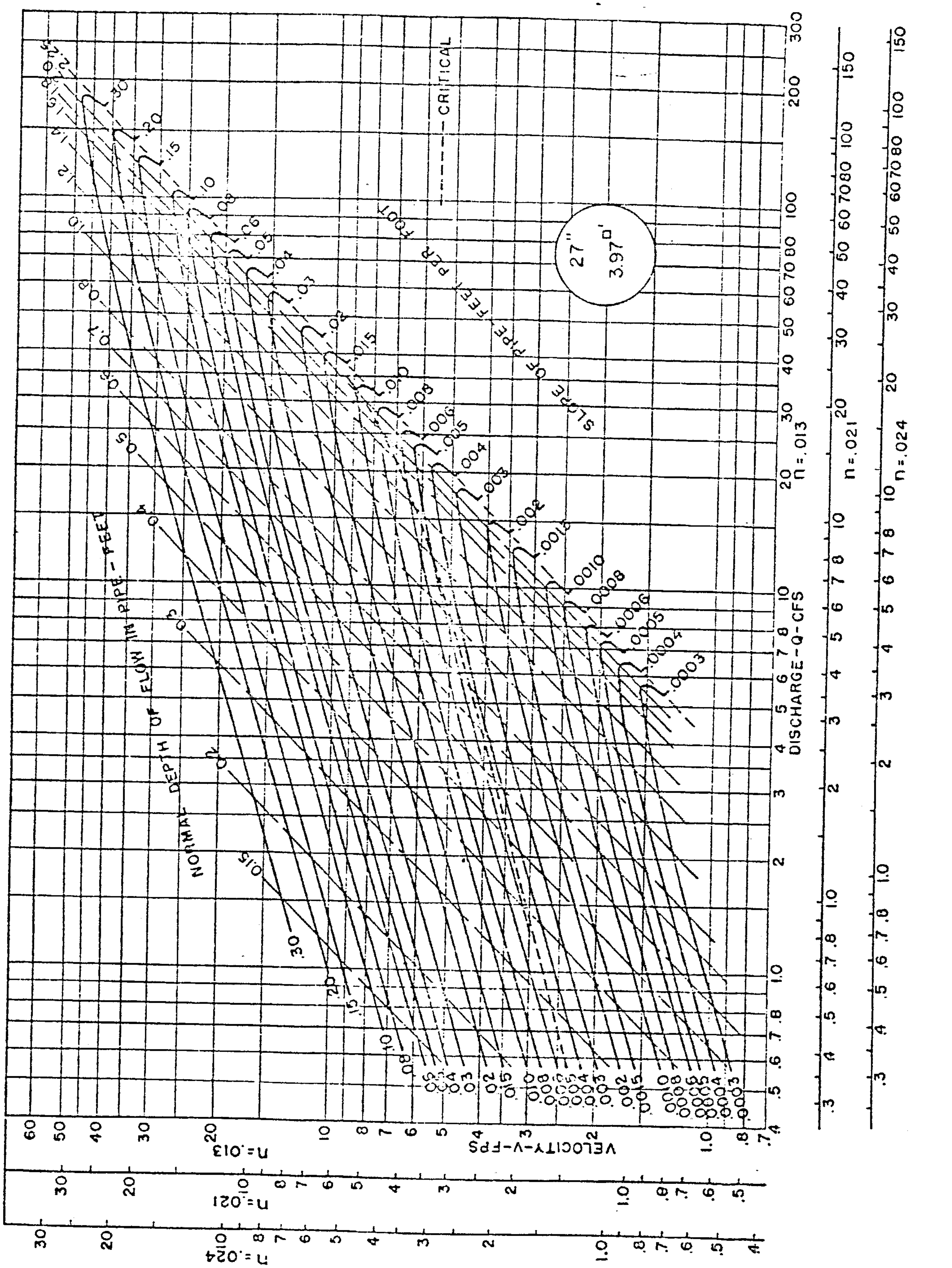
MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61.1 440.21



PIPE FLOW CHART 24" DIAMETER **SD-A-** 33

IV-3-8-7.

MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61.1-440.24

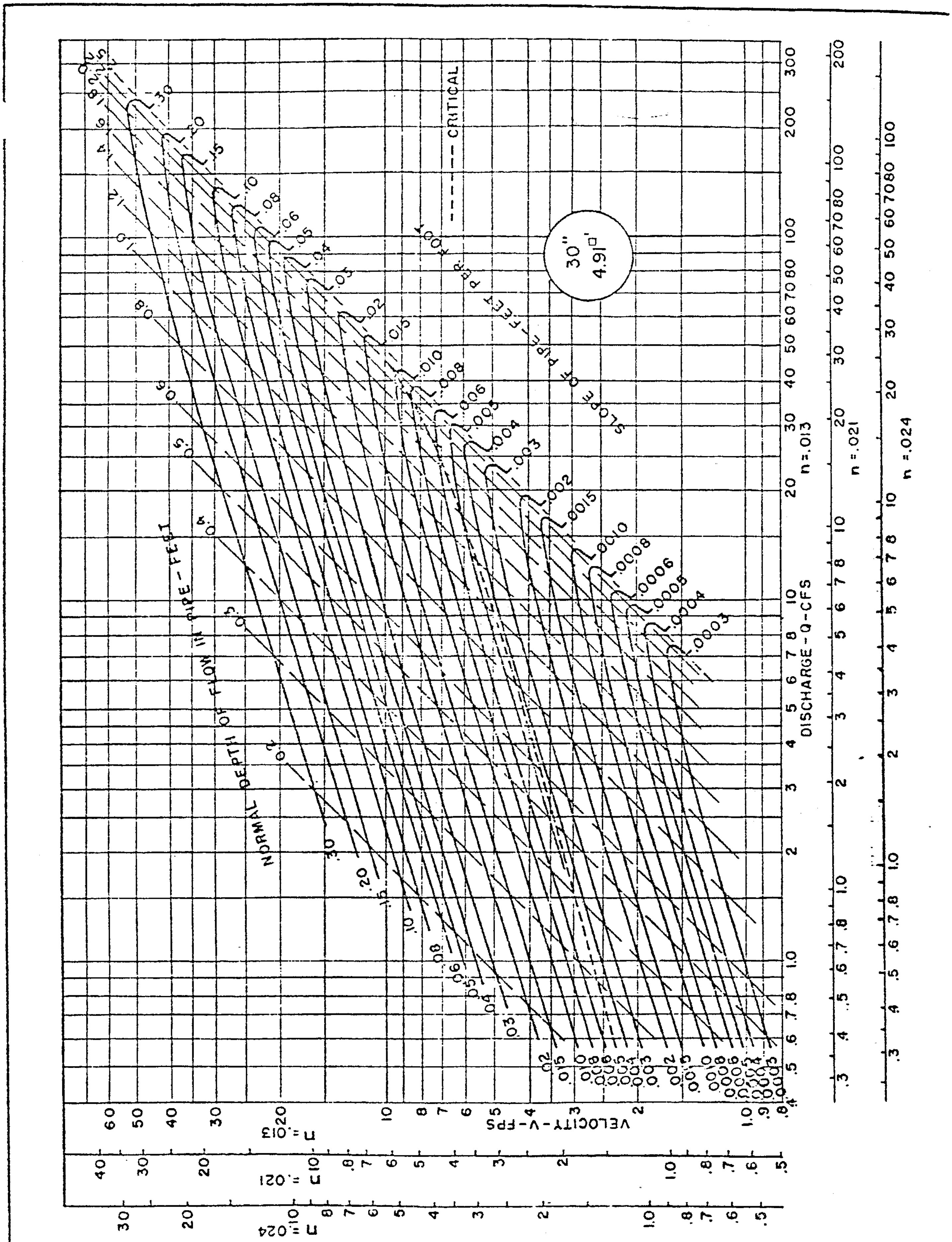


SD-A- 34

PIPE FLOW CHART 27" DIAMETER

IV-3-8-8

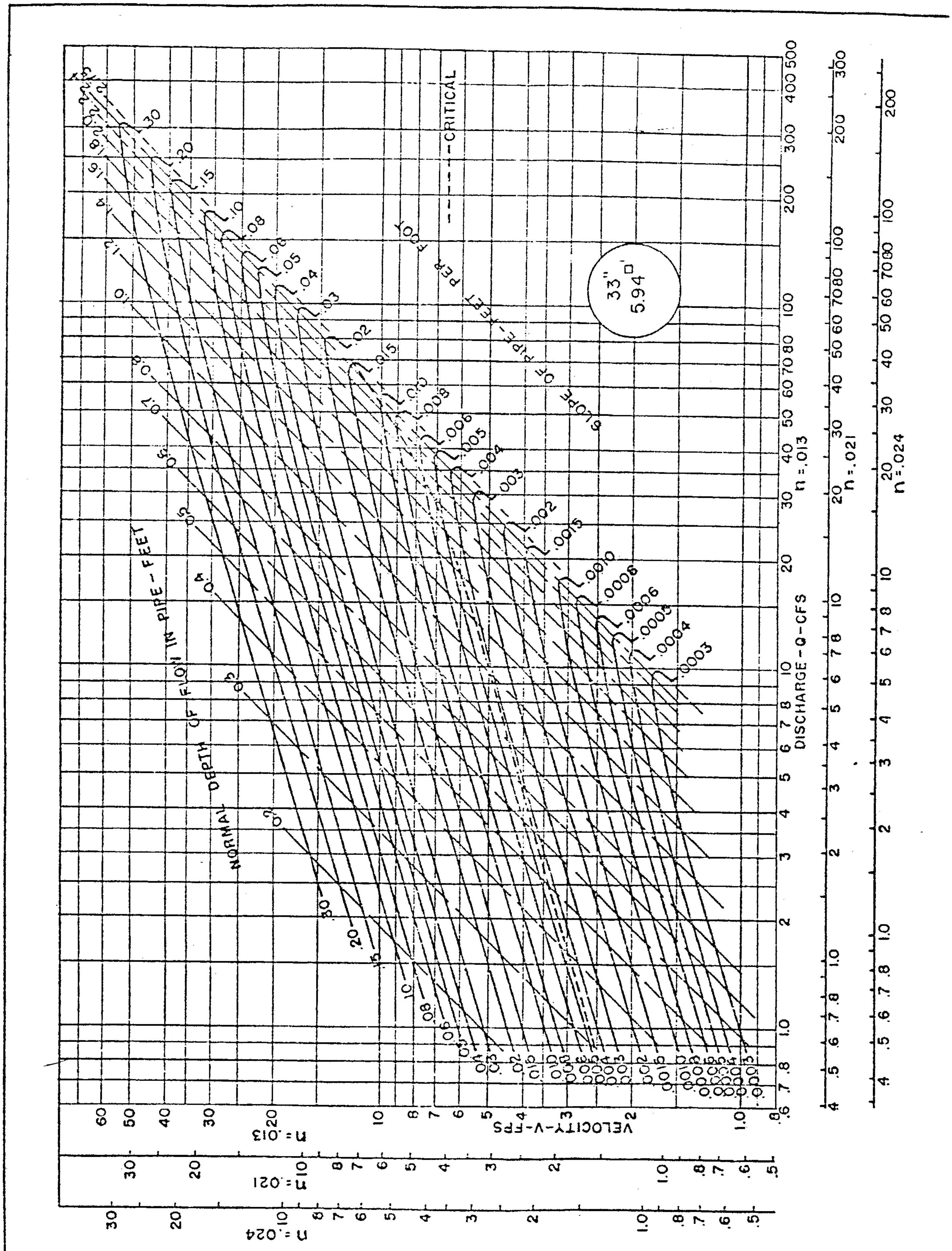
MARYLAND STATE HIGHWAY ADMINISTRATION 8/61



PIPE FLOW CHART 30" DIAMETER

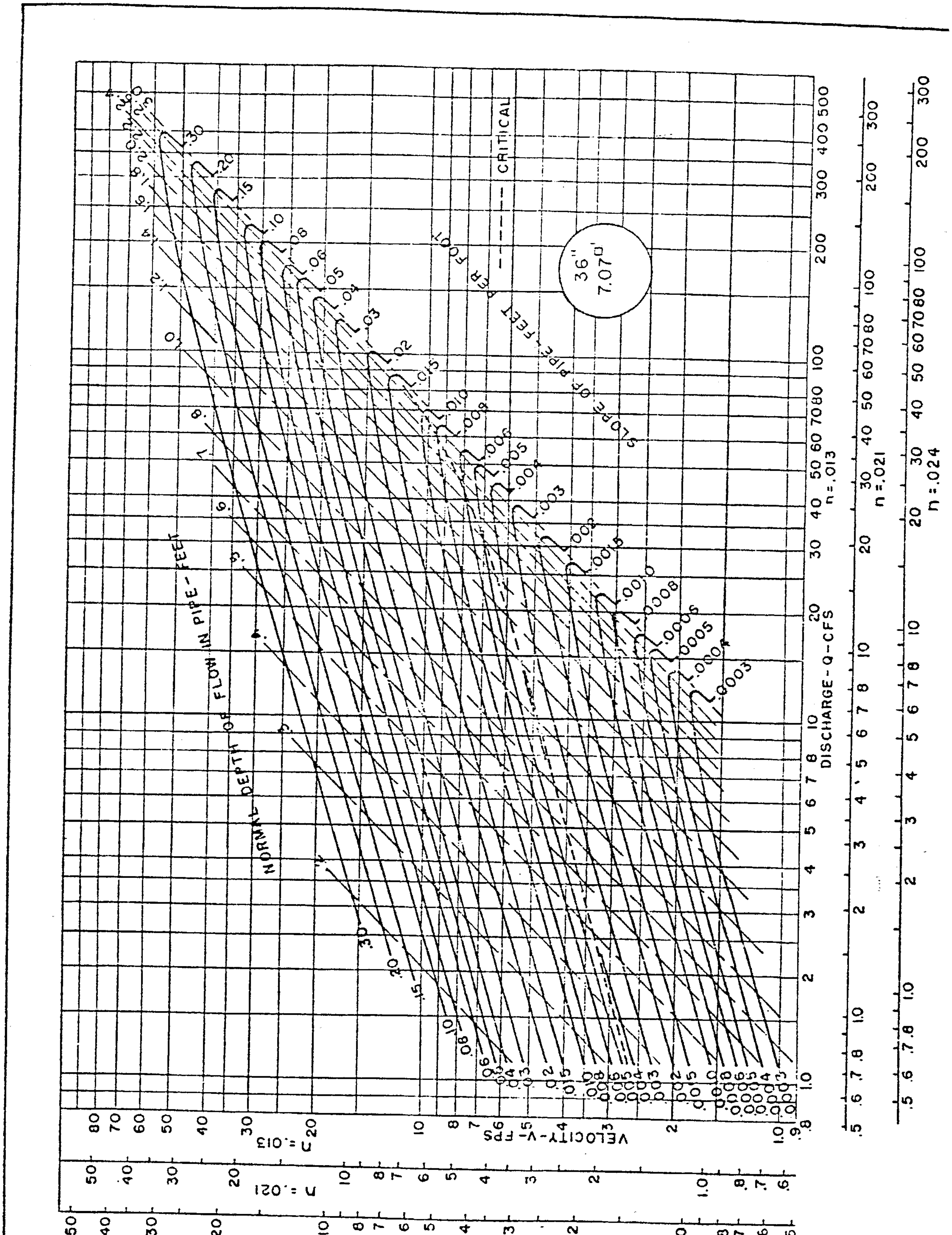
IV-3-G-9

MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61I-440 30



PIPE FLOW CHART 33" DIAMETER **SD-A-** 36

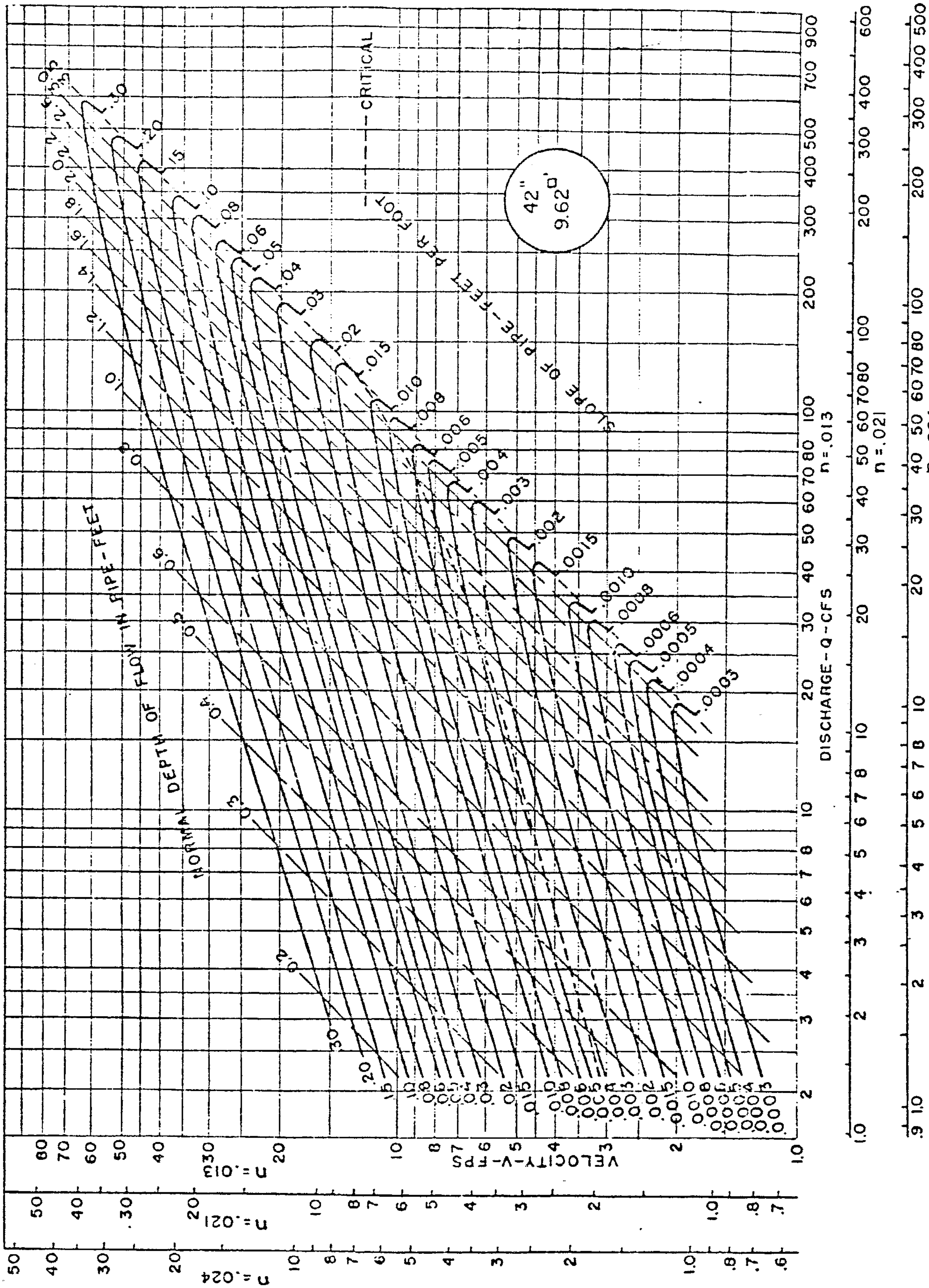
IV-3-8-10



PIPE FLOW CHART 36" DIAMETER **SD-A-** 37

IV-3-8-11

MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61.1-440.36

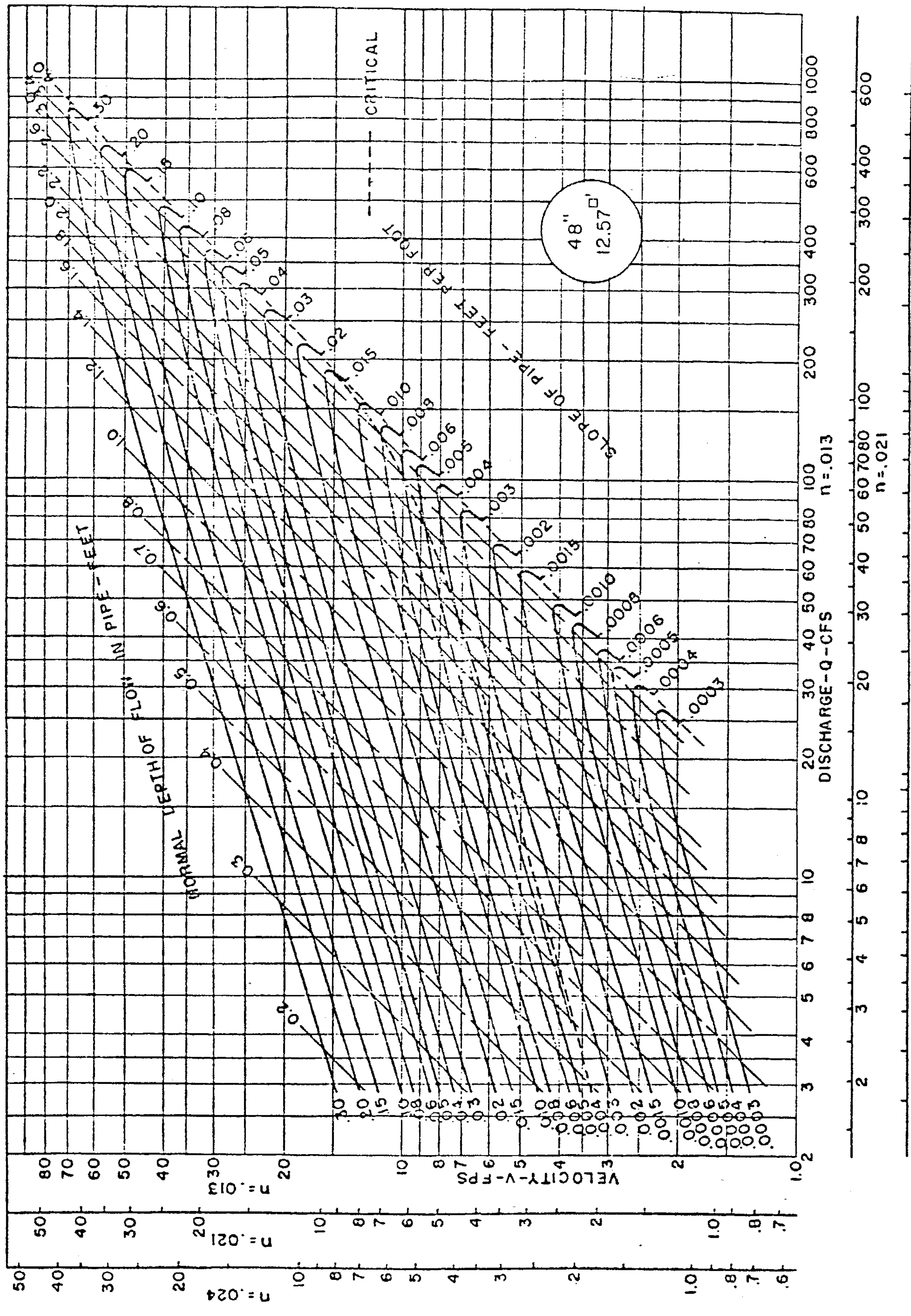


SD-A- 38

PIPE FLOW CHART 42" DIAMETER

IV 3-8-12

MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61.1-440.42

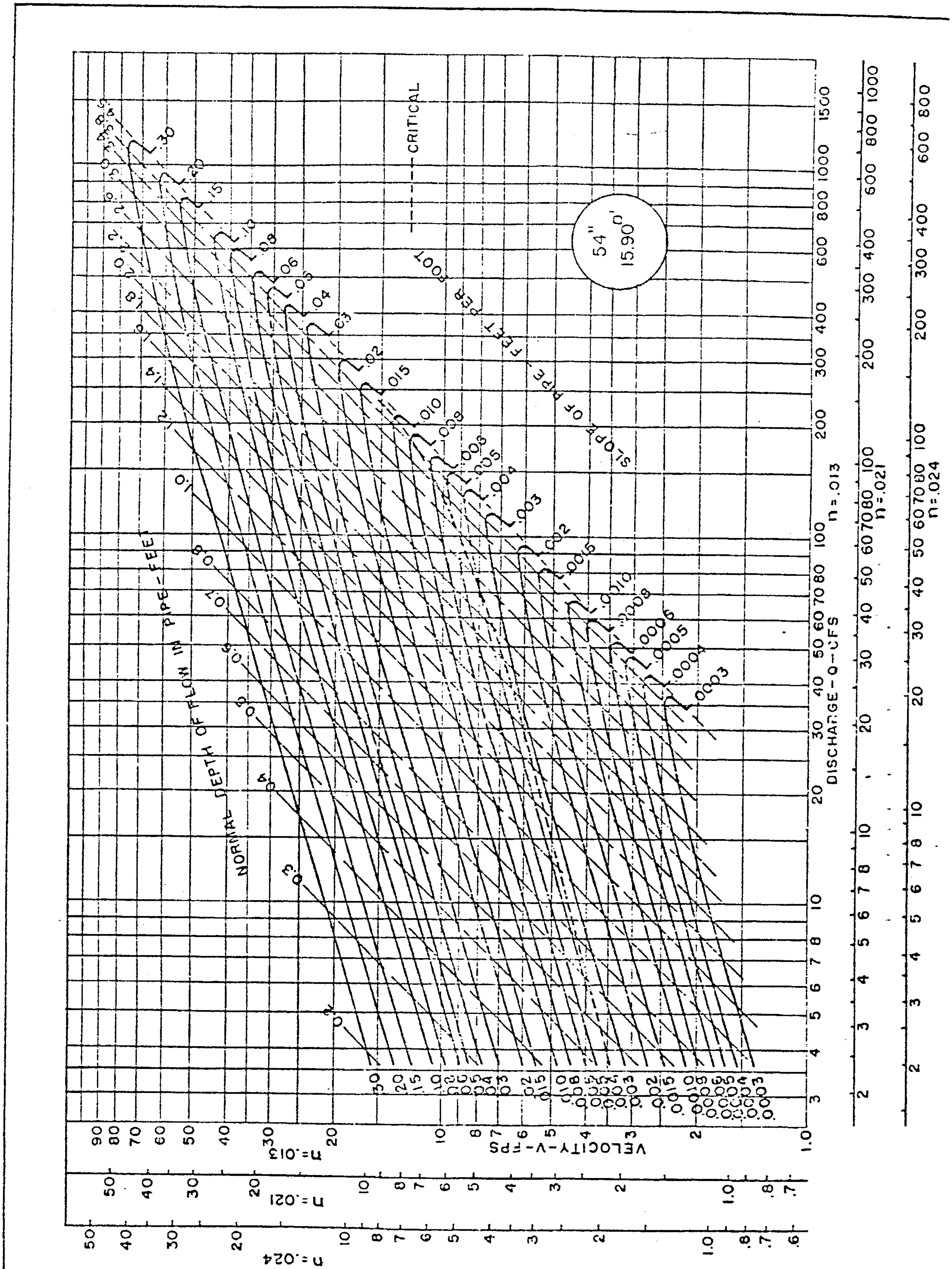


PIPE FLOW CHART 48" DIAMETER

SD-A- 39

IV-3-8-13

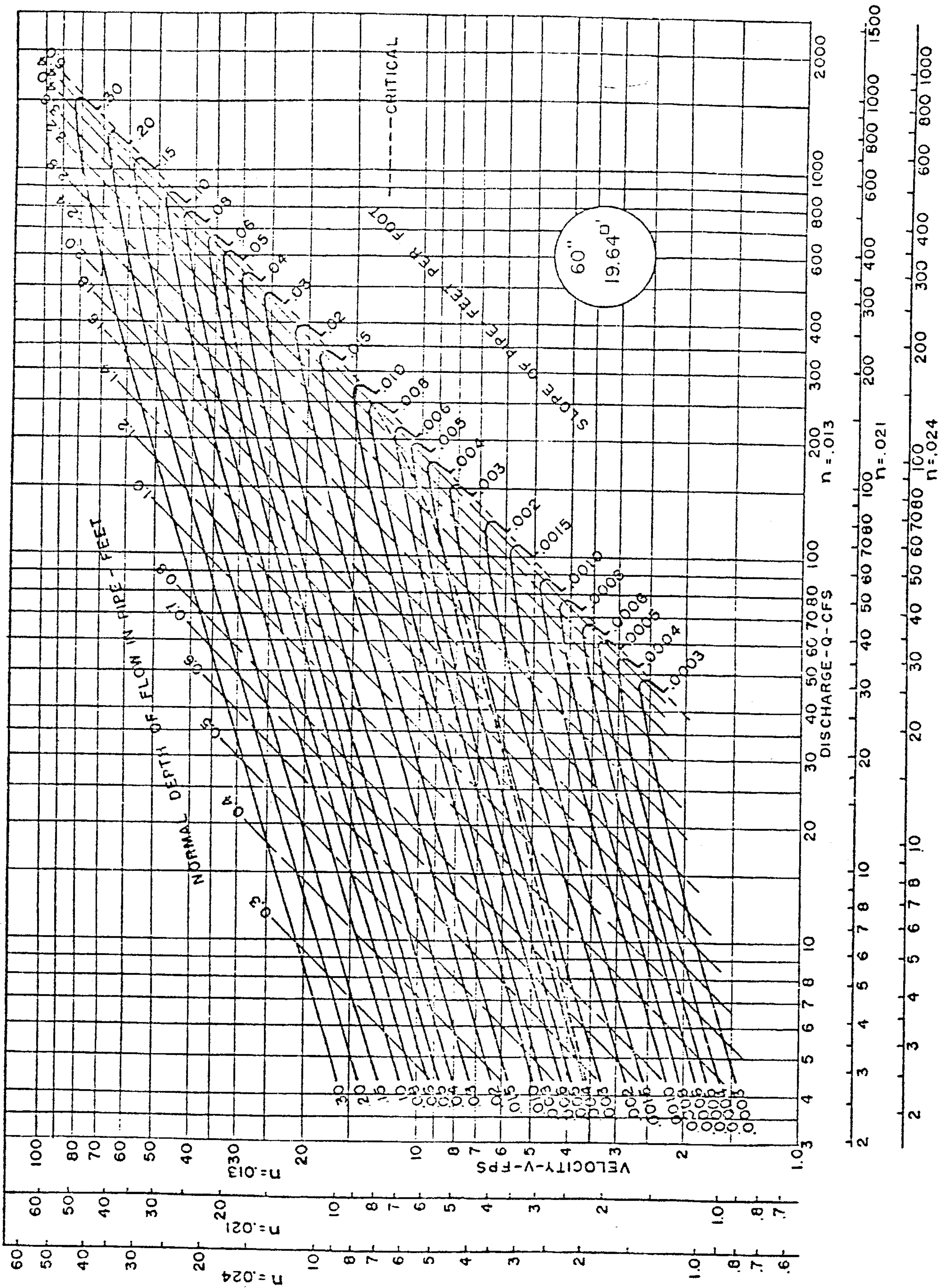
MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61.1-440.48



PIPE FLOW CHART 54" DIAMETER **SD-A-** 40

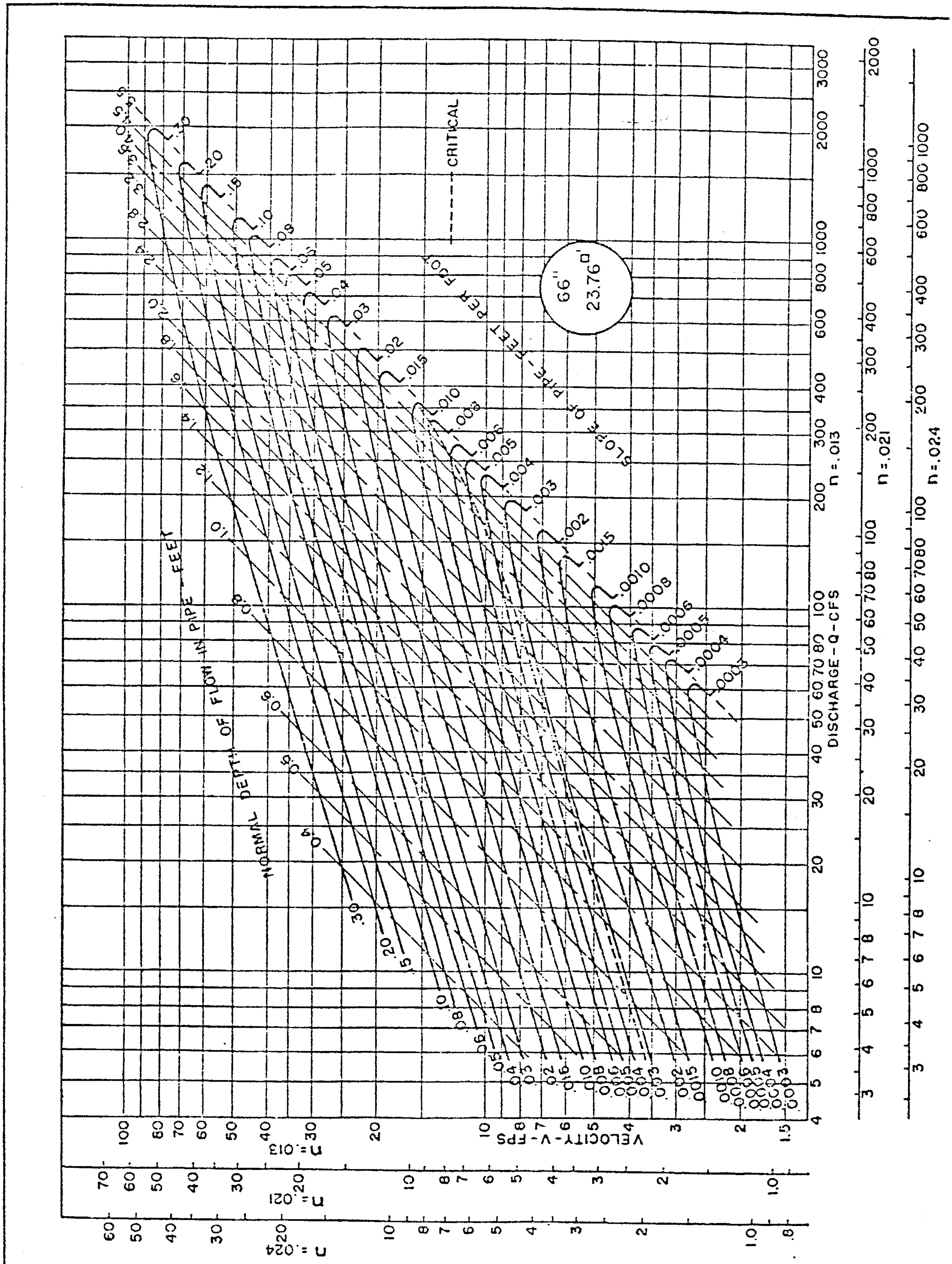
IV-3-8-14

MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61.1-44054



PIPE FLOW CHART 60" DIAMETER

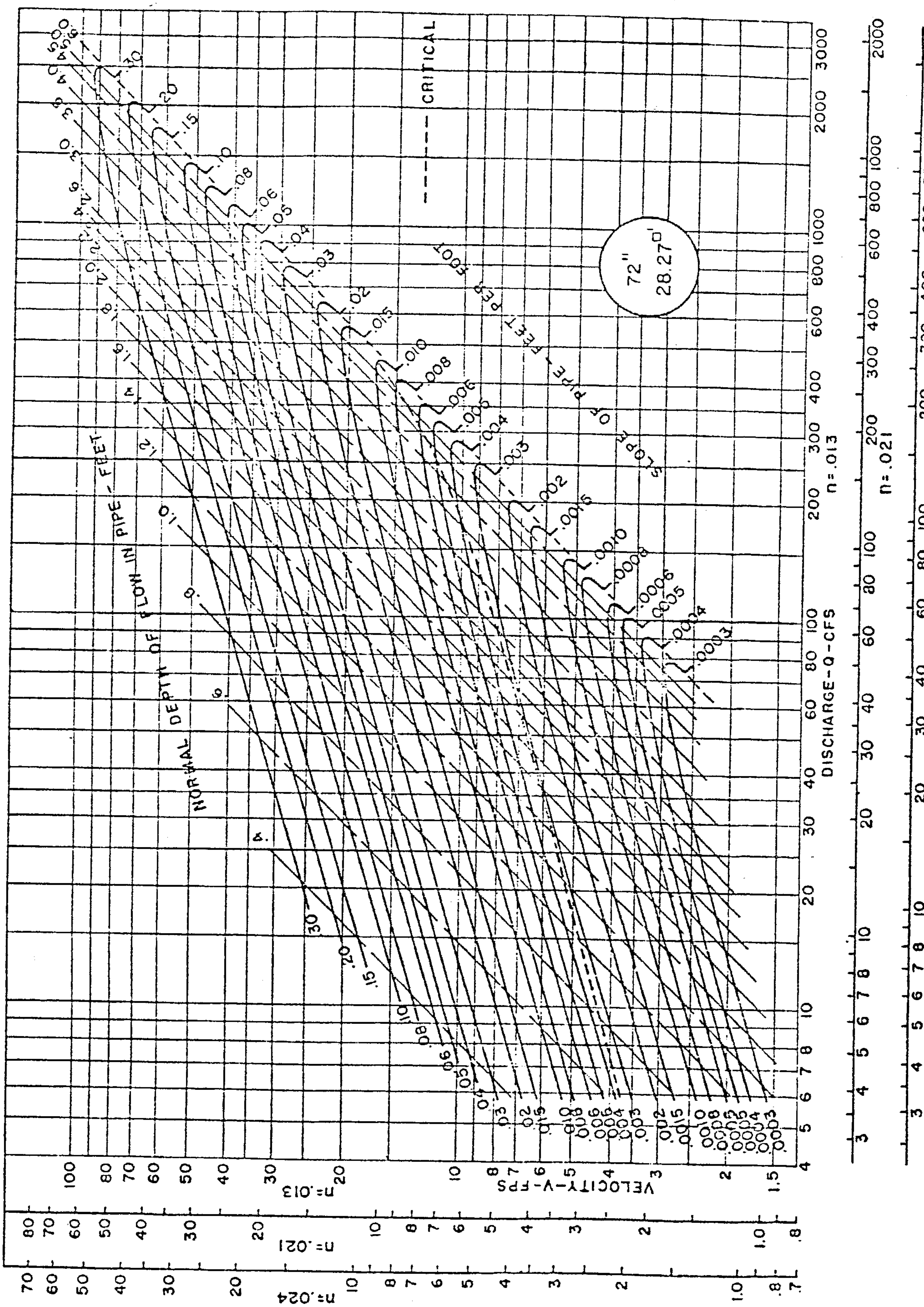
MARYLAND STATE HIGHWAY ADMINISTRATION



PIPE FLOW CHART 66" DIAMETER

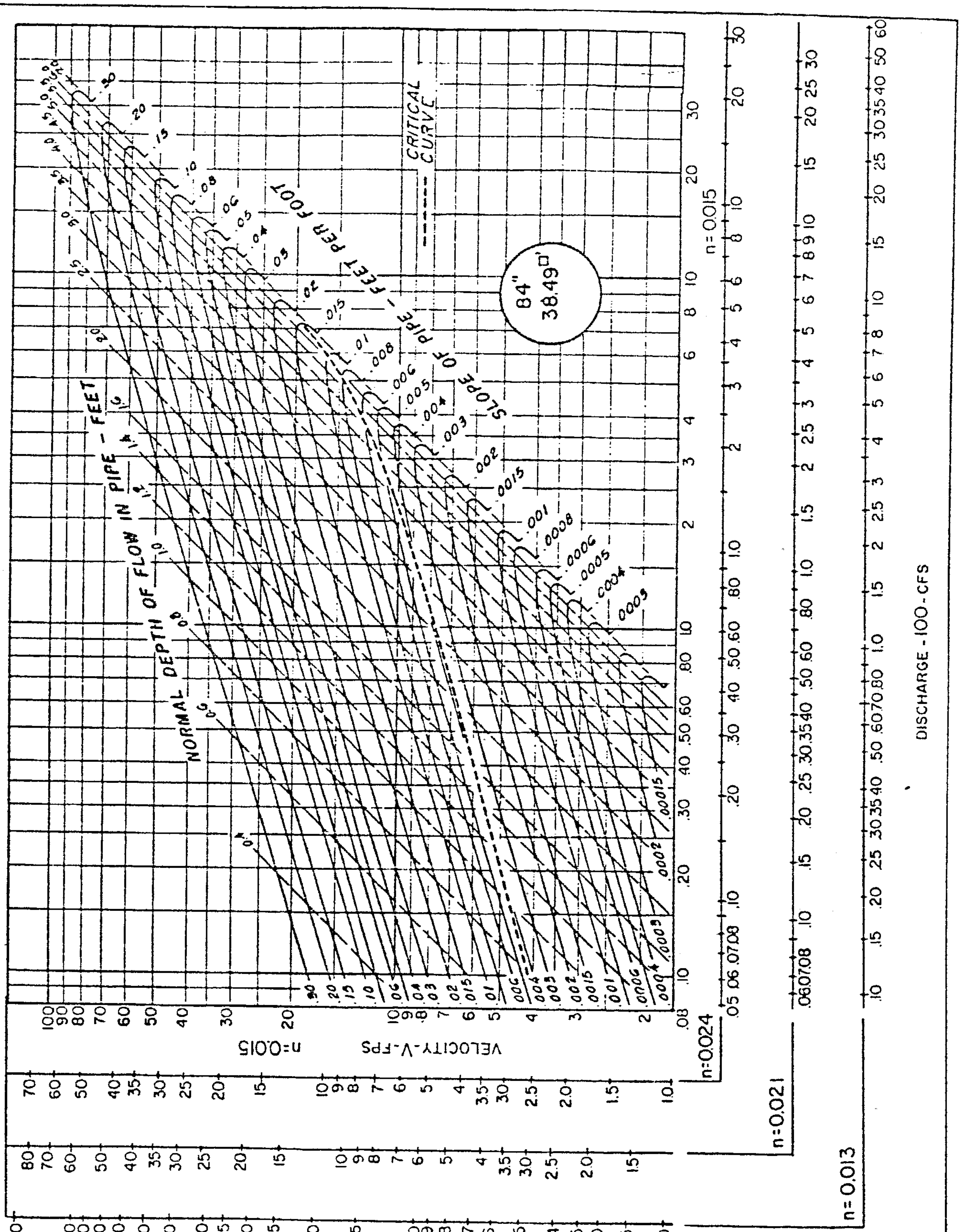
IV-3-8-16

MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA 61.1 440.66



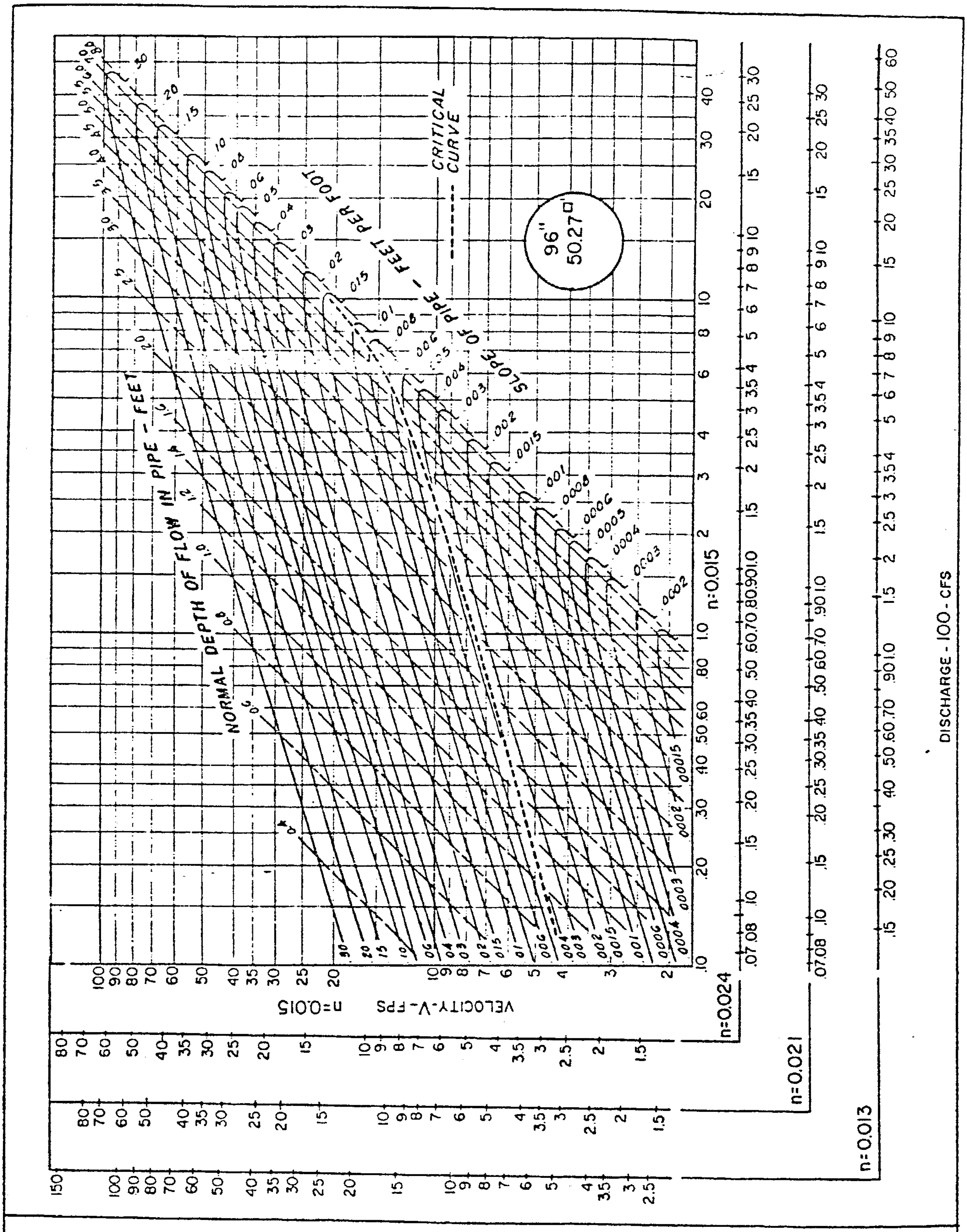
PIPE FLOW CHART 72" DIAMETER **SD-A-** 43 IV-3-8-17

MARYLAND STATE HIGHWAY ADMINISTRATION 8/61 SHA-61.1-440.72



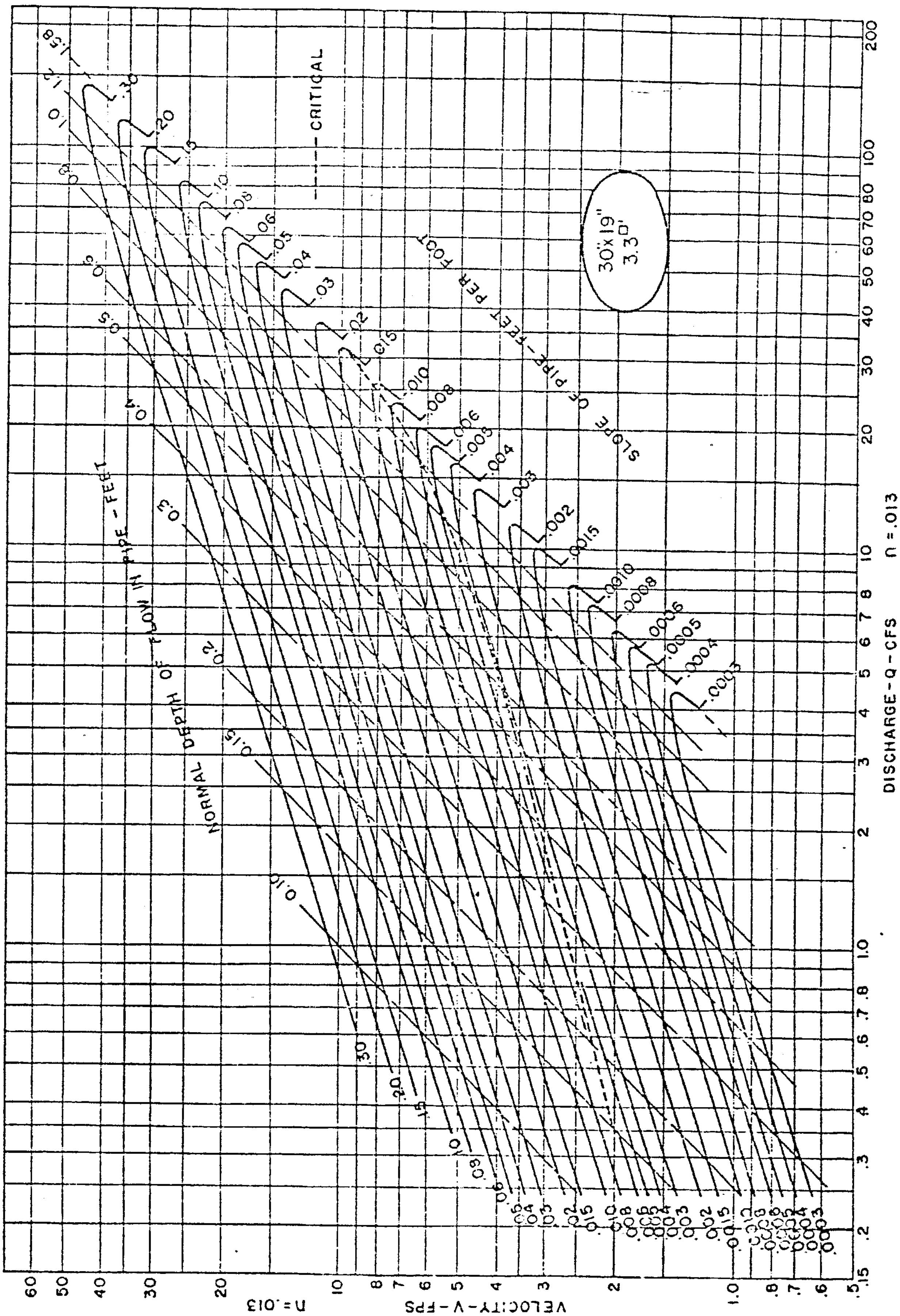
PIPE FLOW CHART-84 INCH DIAMETER

MARYLAND STATE HIGHWAY ADMINISTRATION 9/78 SHA-61.1-440.84



PIPE FLOW CHART 96-INCH DIAMETER

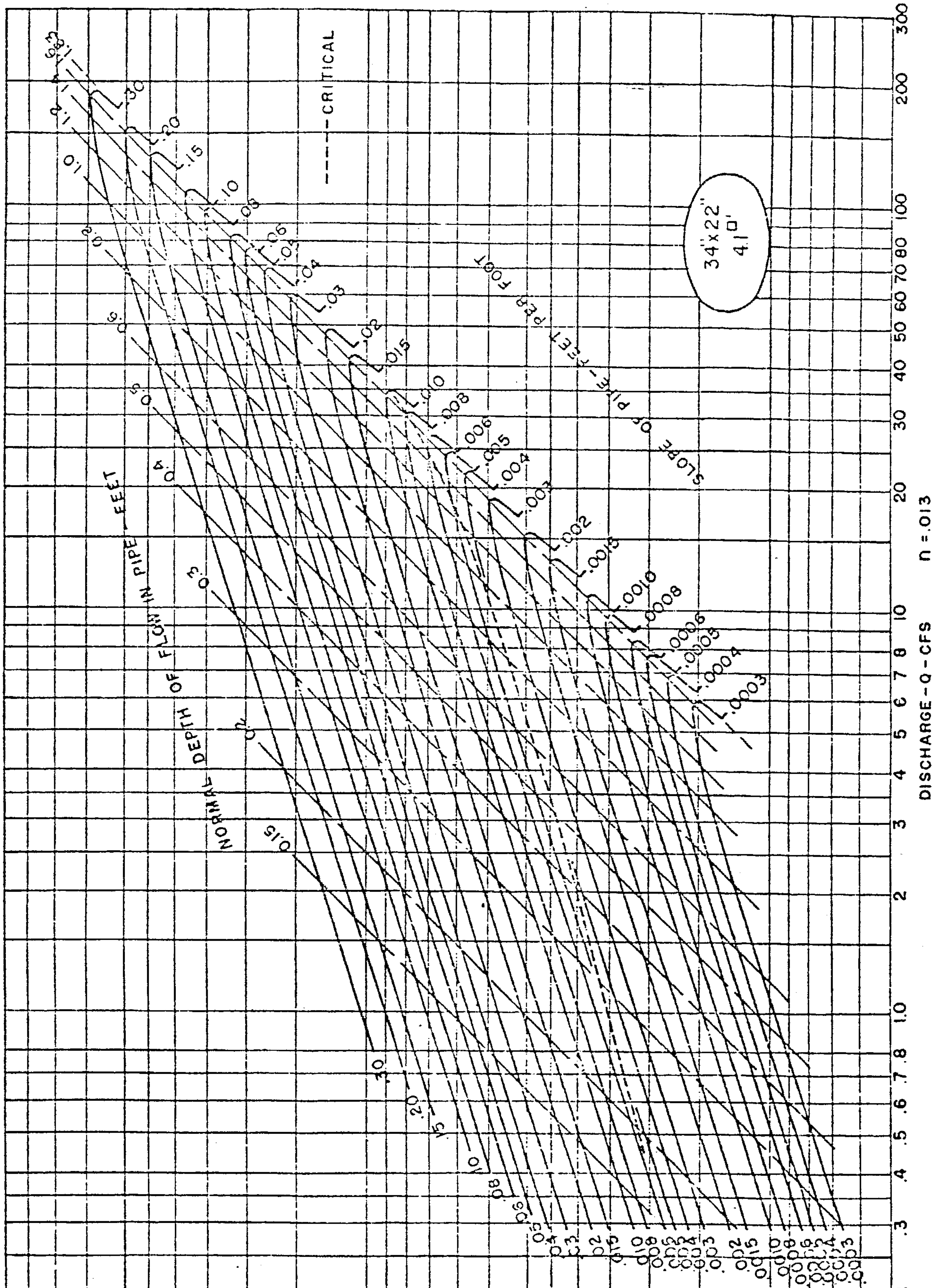
MARYLAND STATE HIGHWAY ADMINISTRATION 9/78 SHA-61.1-440.96



SD-A- 46

PIPE FLOW CHART, 30"x19" CONCRETE ELLIPTICAL PIPE

IV-3-9-2

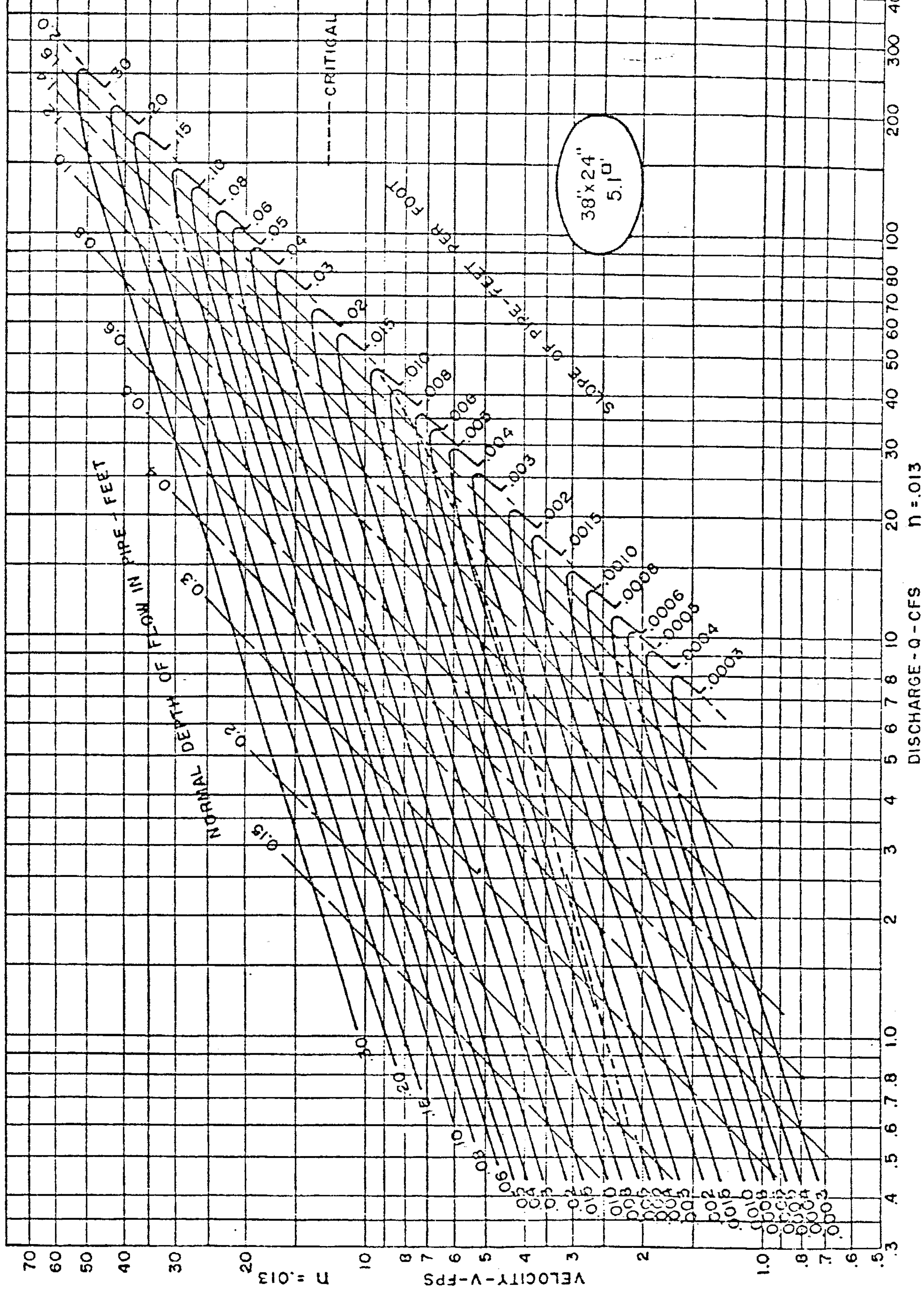


SD-A- 47

PIPE FLOW CHART, 34"x 22" CONCRETE ELLIPTICAL PIPE

IV-3-9-3

MARYLAND STATE HIGHWAY ADMINISTRATION 12/61 SHA-61.1-44134-22

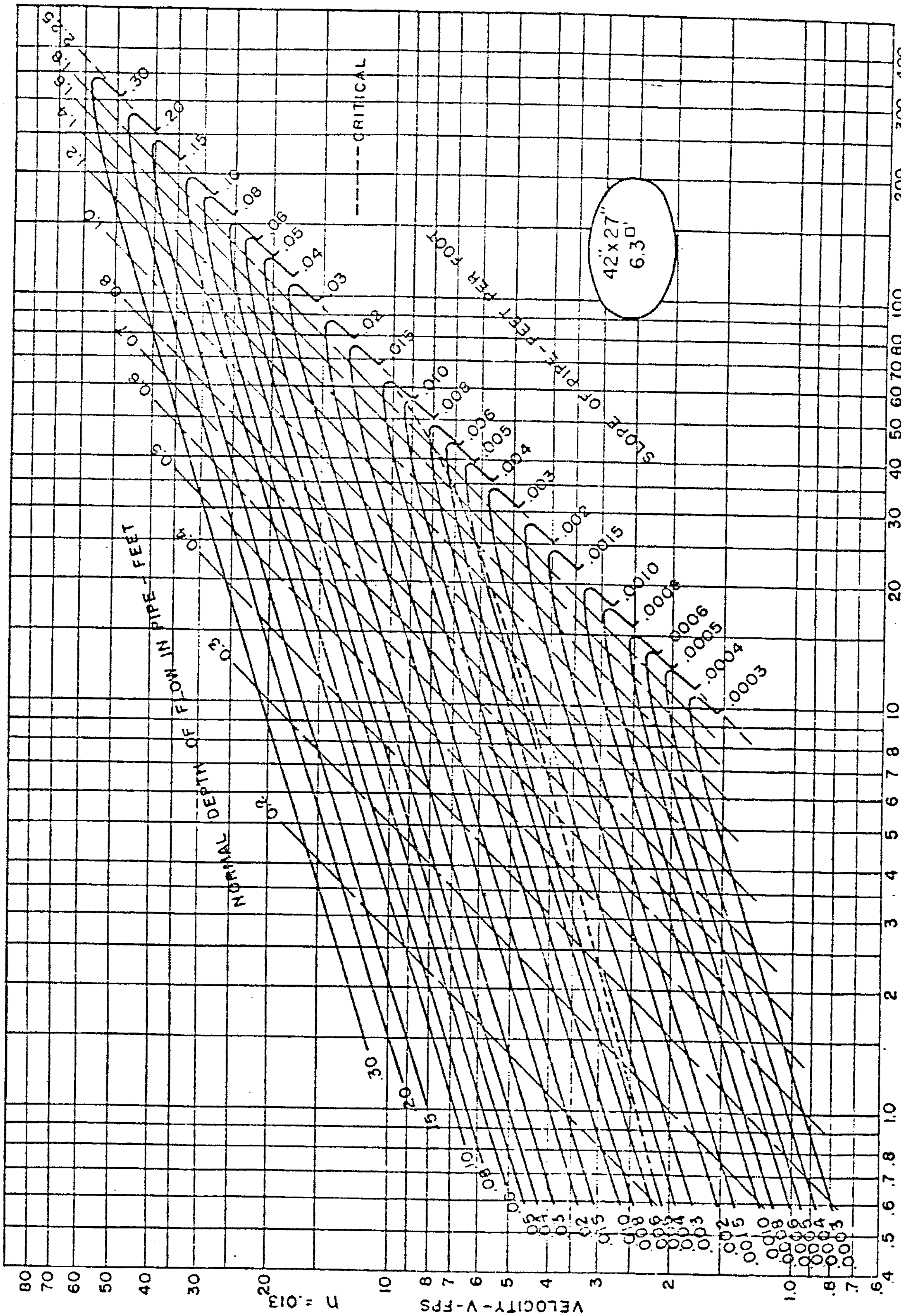


SD-A- 48

PIPE FLOW CHART, 38"x24" CONCRETE ELLIPTICAL PIPE

IV-3-9-4

MARYLAND STATE HIGHWAY ADMINISTRATION 12/61 SHA-61.1-441 38-24

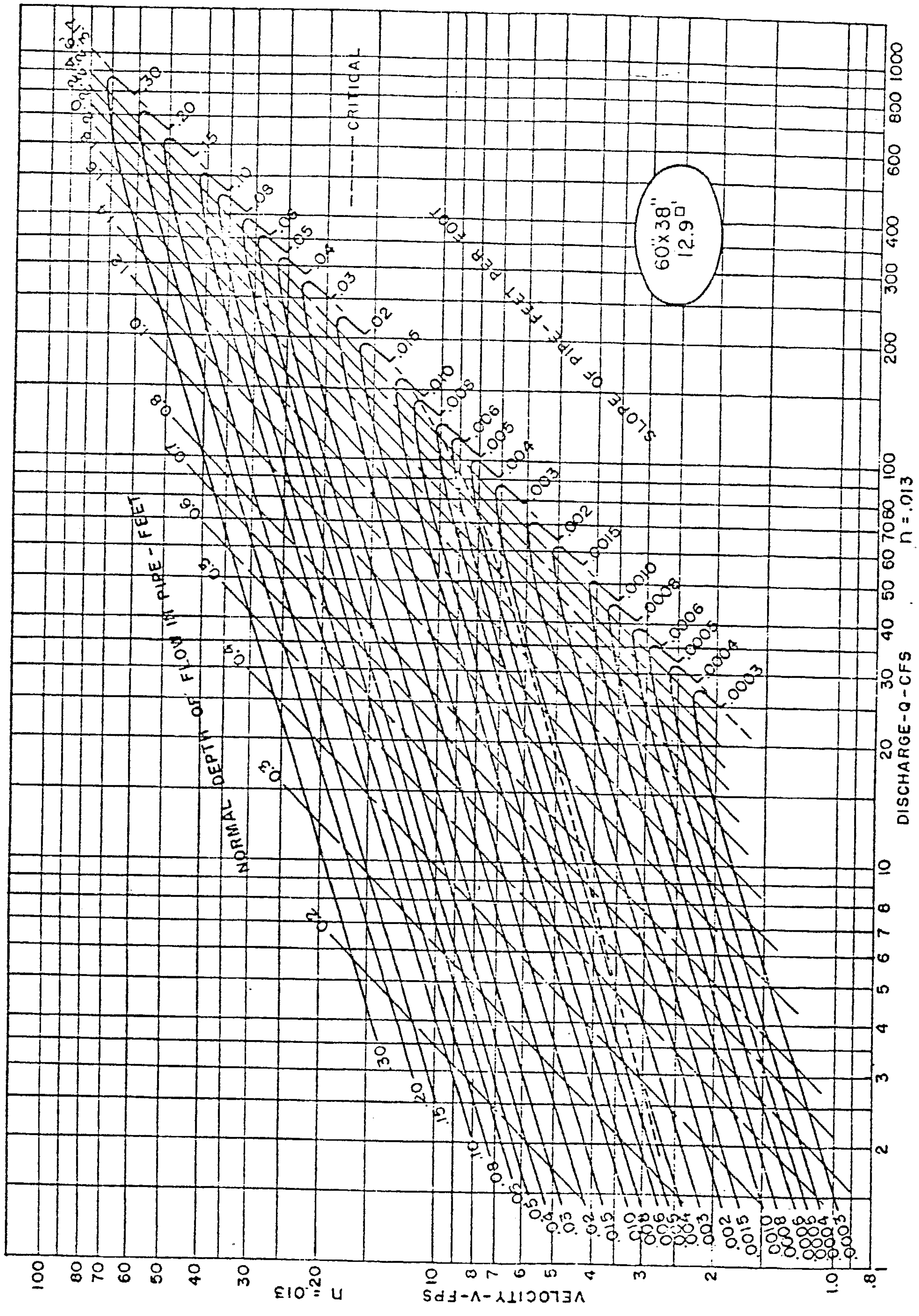


SD-A-49

PIPE FLOW CHART, 42"x27" CONCRETE ELLIPTICAL PIPE

IV-3-9-5

MARYLAND STATE HIGHWAY ADMINISTRATION 12/61 SHA-61.1-441.42-27

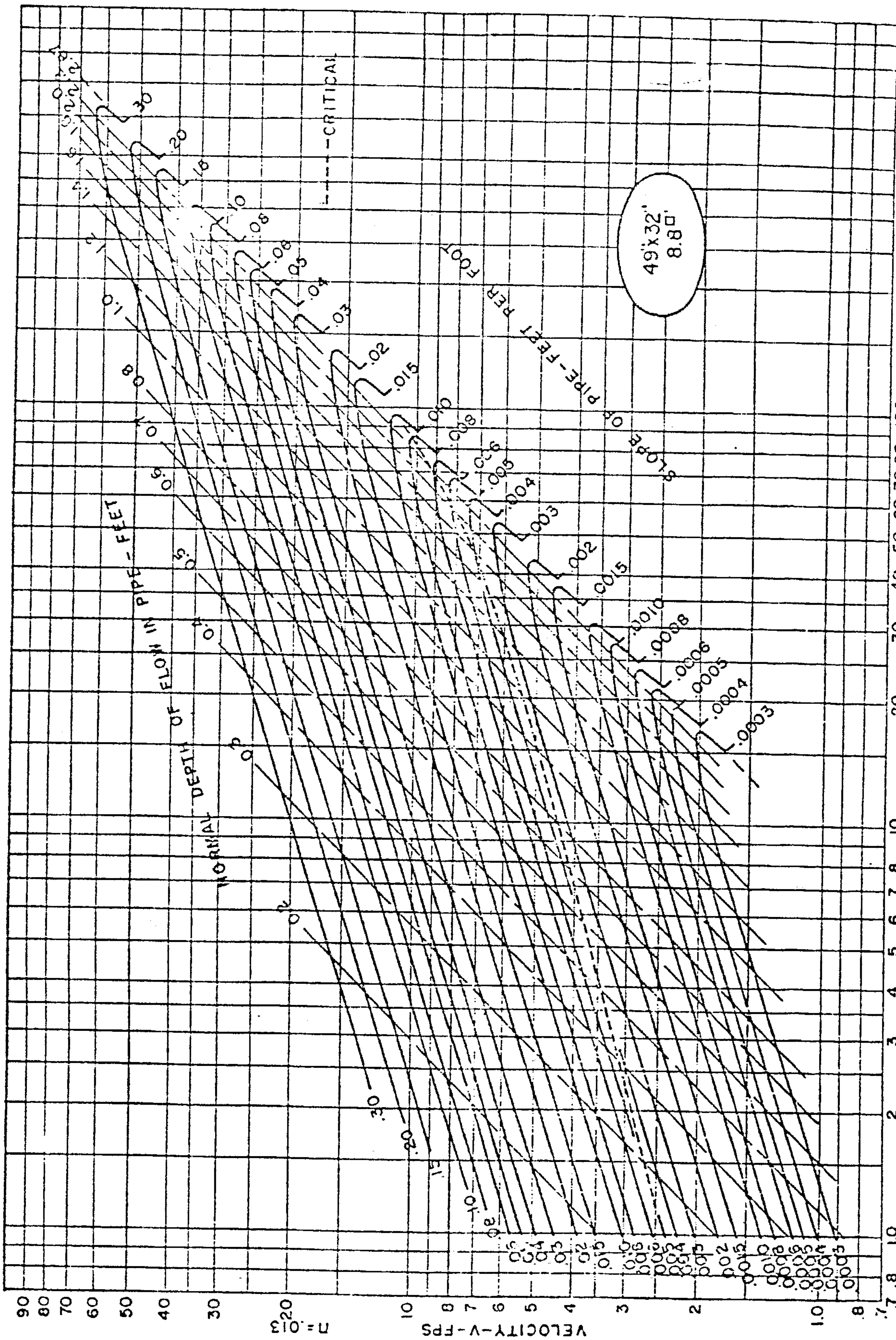


SD-A- 50

PIPE FLOW CHART, 60"x38" CONCRETE ELLIPTICAL PIPE

IV-3-9-9

MARYLAND STATE HIGHWAY ADMINISTRATION 12/61

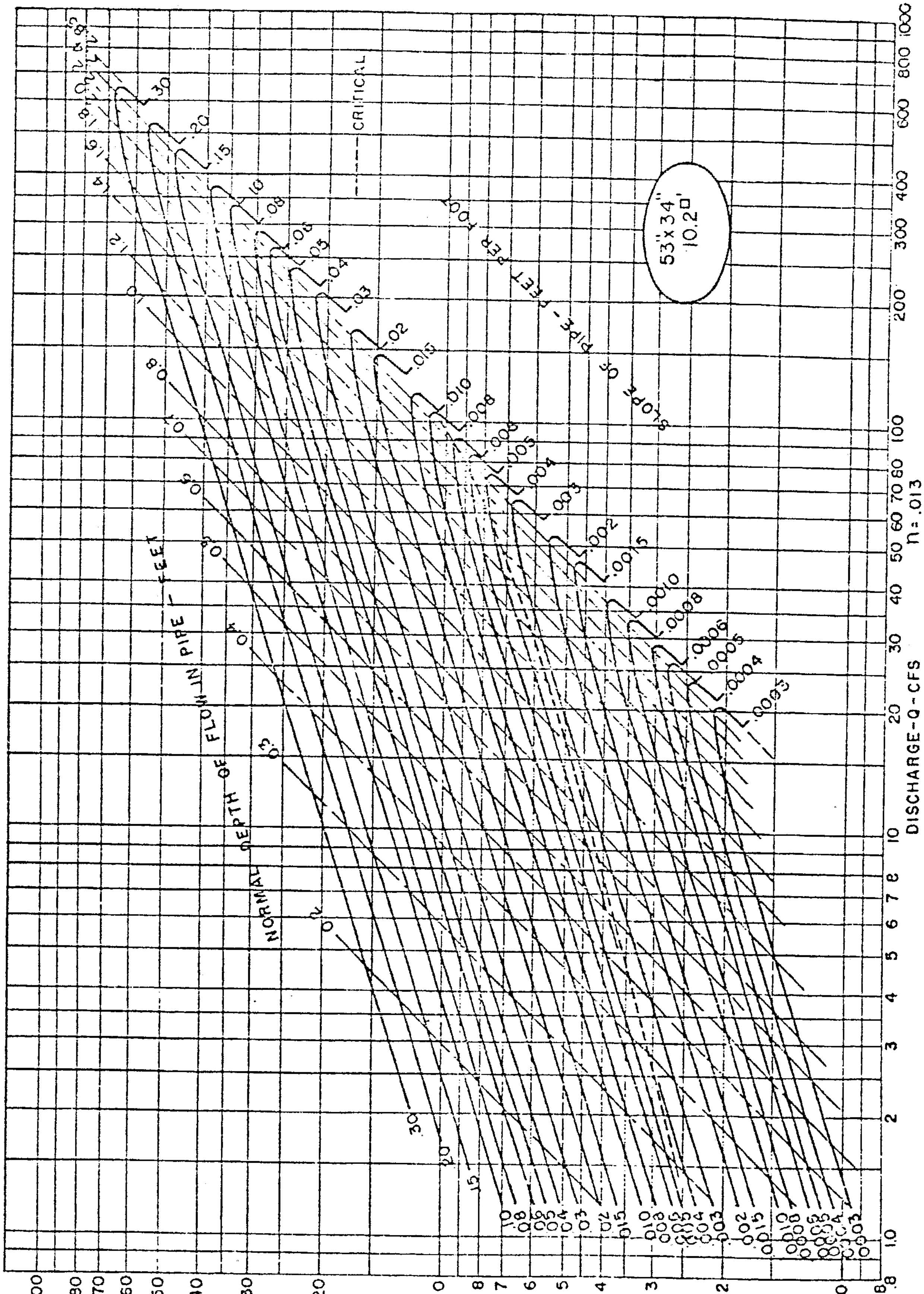


SD-A- 51

PIPE FLOW CHART, 49"x32" CONCRETE ELLIPTICAL PIPE

IV-3-9-7

MARYLAND STATE HIGHWAY ADMINISTRATION 12/61 SHA-61-44149-32

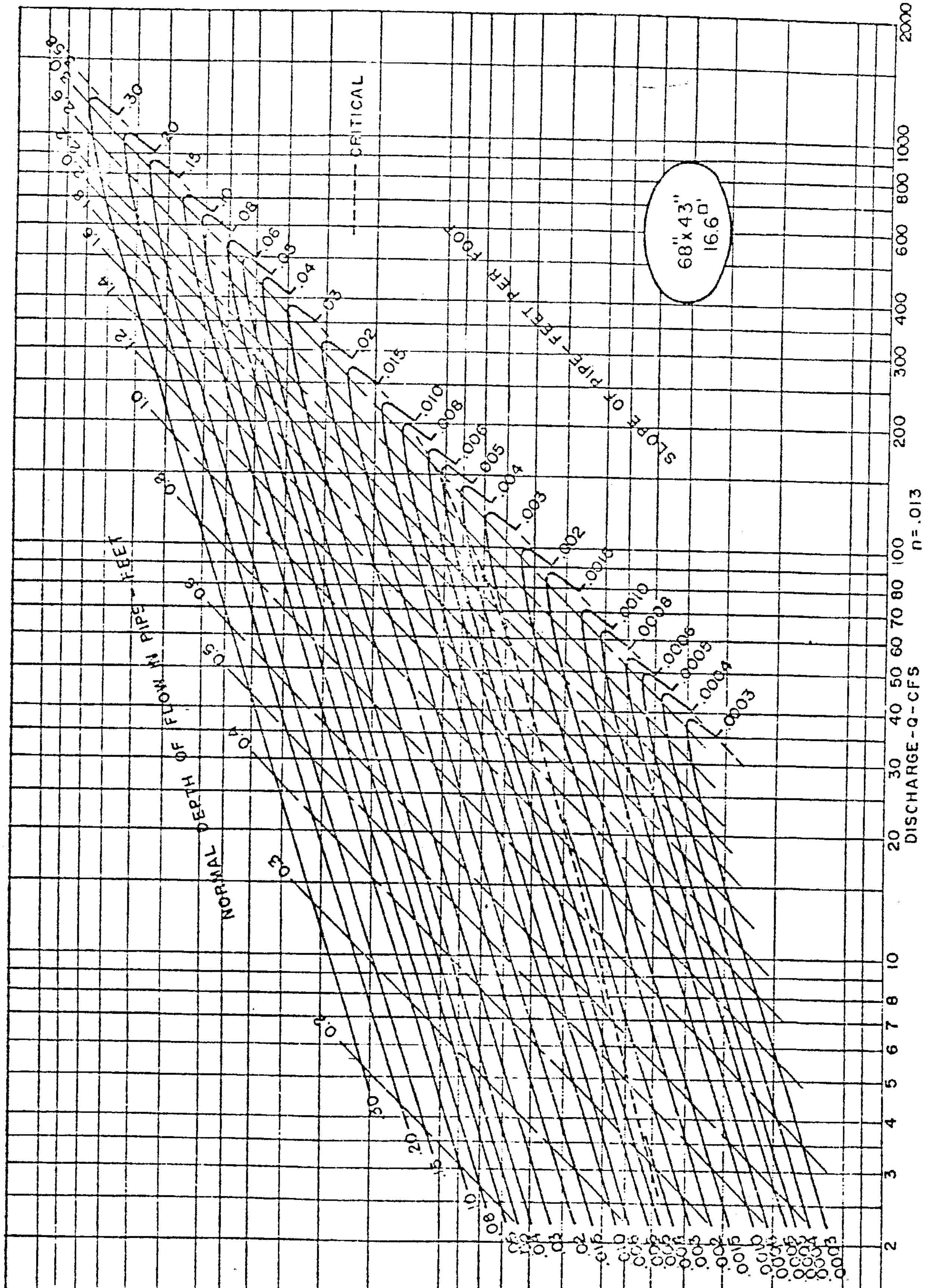


SD-A- 52

PIPE FLOW CHART, 53"x34" CONCRETE ELLIPTICAL PIPE

IV-3-9-8

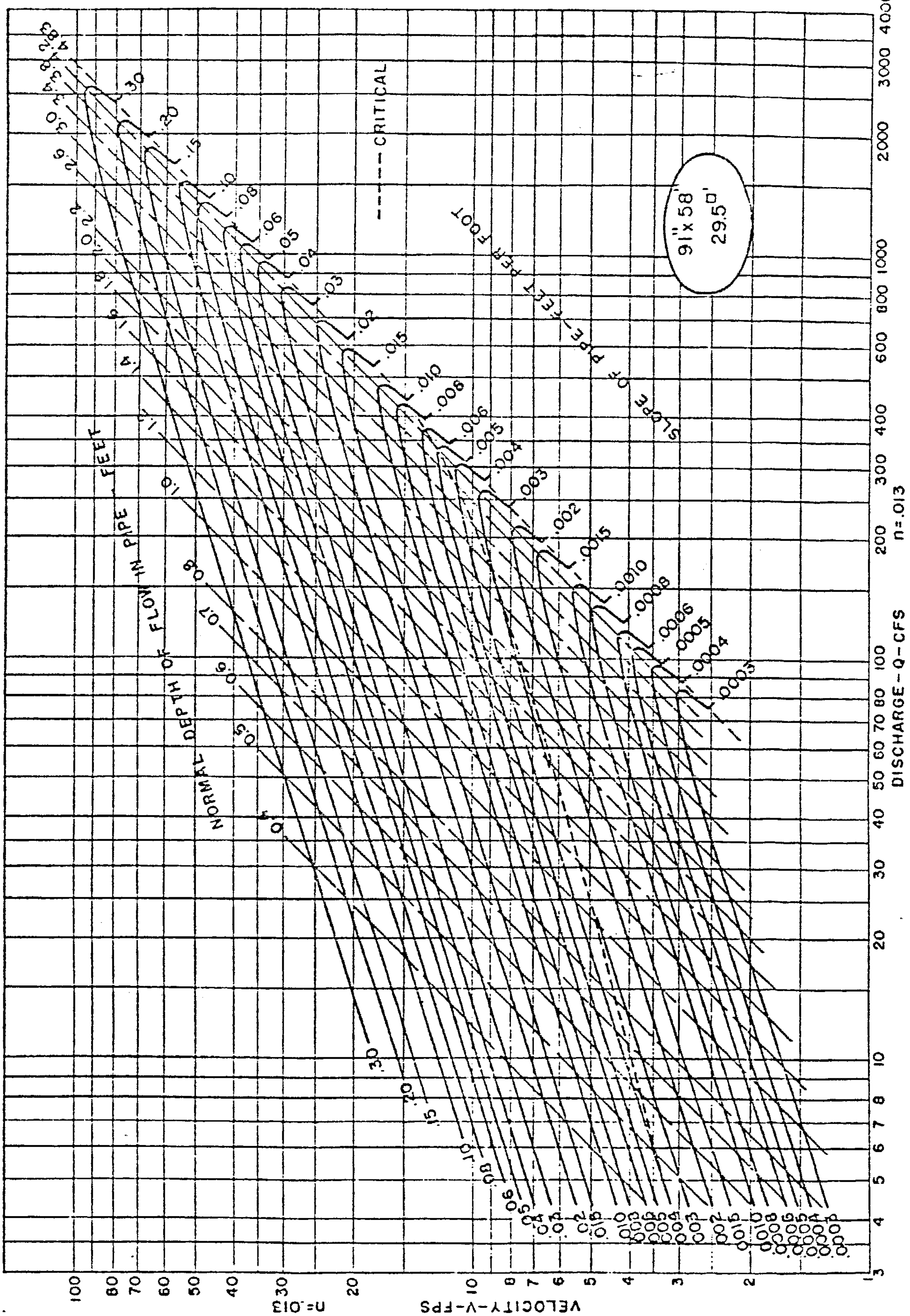
MARYLAND STATE HIGHWAY ADMINISTRATION 12/61 SHA-61I-44I 53-34



SD-A- 53

PIPE FLOW CHART, 68"x43" CONCRETE ELLIPTICAL PIPE

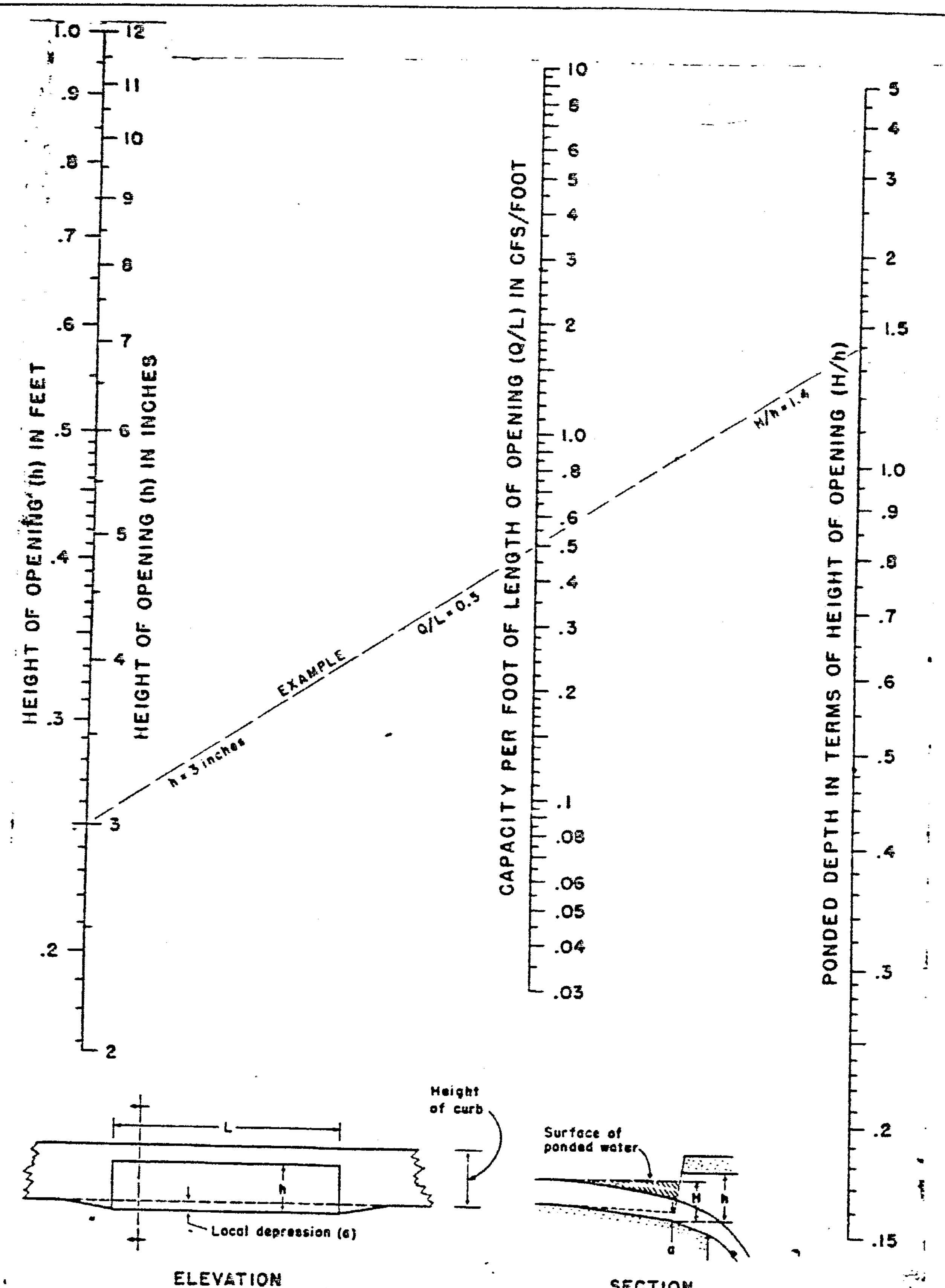
IV-3-9-10



SD-A- 54

PIPE FLOW CHART, 91"x58" CONCRETE ELLIPTICAL PIPE

IV-3-9-13



CAPACITY OF CURB OPENING INLET AT LOW POINT IN GRADE

SD-A- 55

AS-BUILT DRAWING

I HEREBY STATE, TO THE BEST OF MY KNOWLEDGE AND PERSONAL BELIEF, THAT THE WORK SHOWN ON THESE PLANS WAS CONSTRUCTED TO THE LINES AND GRADES SHOWN.

ENGINEER DATE P.E. NO.

	AS-BUILT DRAWING STATEMENT **SD-A-** 56	CITY OF BRUNSWICK